October 1958

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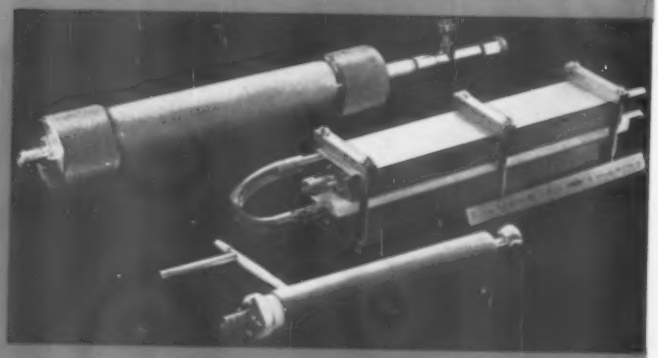
NUCLEONICS

ATOMIC POWER • NUCLEAR ENGINEERING • APPLIED RADIATION



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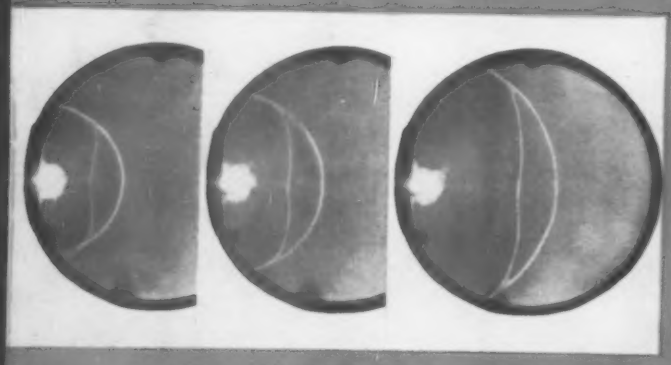

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'59 PLAN

Modernize now for growth and profits

A SPECIAL REPORT FROM McGRAW-HILL TO AMERICA'S BUSINESS EXECUTIVES —SEE P. 61

The DS8 basic scintillation detector weighs less than 5 ounces, and is just 1" in diameter.

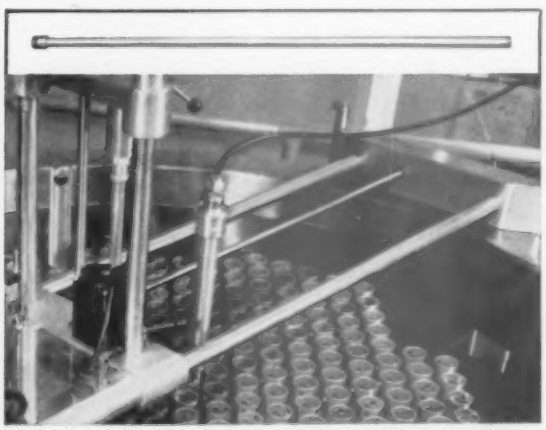
Versatile New Scintillation Probe Detects Fast or Slow Neutrons, Gammas, and Betas

Completely new, the Nuclear-Chicago Model DS8 Scintillation Probe provides precision detection of fast or slow neutrons, gamma and beta radiation. Utilizing a unique new 10 stage, ¾" photomultiplier tube and a completely transistorized electronic circuit, the probe is completely water tight and corrosion proof. A resolution time in the microsecond region permits its use in extremely high radiation fields.

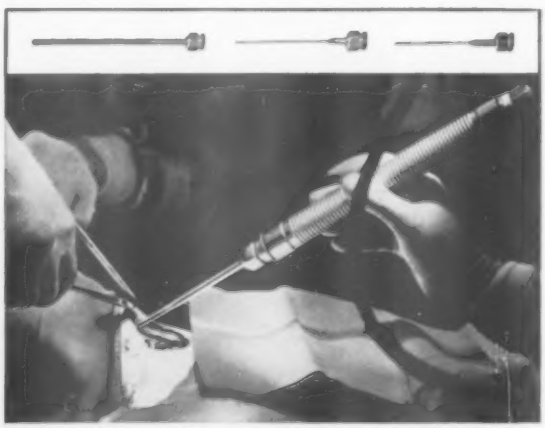
Two neutron probes are offered for flux measurements in reactors or subcritical assemblies. The neutron sensitive volume is confined to the very ends of the 42" probes so that "point" measurements may be made easily. Probe housings are quickly removed to permit substitution of slow neutron or fast neutron sensitive phosphors. These long probes can also be supplied with sodium iodide crystals for gamma detection.

Three needle probes with 2.5 mil wall thicknesses are available for beta and gamma detection. They are unequalled for measuring radiation in almost inaccessable areas where highest resolution is essential.

For more than 12 years we have been designing and manufacturing high quality, dependable instruments for detecting and measuring radioactivity. We will be glad to furnish you complete information on this new DS8 Scintillation Probe or on other Nuclear-Chicago instrumentation or our Research Quality Radiochemicals.



Shown here being used with Nuclear-Chicago Model 9000 Subcritical Training Reactor to measure slow neutron flux at various points in the lattice, neutron probes are 42" long and are available in two diameters, ¾" and 11/32".



Shown here in use during thyroid surgery, Model DS8 is offered with three beta-gamma sensitive needle probes 2 mm, 3 mm and 6 mm in diameter, 10 cm to 15 cm in length. All probes are easily interchanged by loosening a simple hand nut.

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NUCLEONICS

ATOMIC POWER
NUCLEAR ENGINEERING
APPLIED RADIATION

VOLUME 16 NUMBER 10

OCTOBER 1958

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About NUCLEONICS

A Rose By Any Other Name

Starting with this issue of NUCLEONICS our Cross Sections department, which is the oldest in point of service, dating back to January of 1950, is rechristened "Instrumentation and Measurements." We have felt for some time now that the name "Cross Sections" was not sufficiently descriptive of the content of the department. More than anything else, the name reflected the fact that many kinds of things could be found there and, except for the nuclear connotation of the name Cross Sections, it might as well have been called "Olla-Podrida."

"Instrumentation and Measurements" is intended to be more descriptive of the material that we carry there—certainly, the change in name reflects no diminution in our interest in nuclear techniques—we are still eager for articles of the type that have filled Cross Sections in the past. If you have any up your sleeve let us know.

Serving the Reader

The change in name of one of our departments as discussed above is one small aspect of the continuing concern for the proper satisfaction of the readers' interest that is an editor's greatest concern. In a field as complex and variegated as the nuclear field this is a particularly challenging responsibility. We of NUCLEONICS attempt to fulfill that responsibility by continually sampling reader response to our articles (perhaps you've received one of our post-card surveys or been visited by one of our interviewers) and carefully balance our editorial content to the interests thus revealed.

The Anti-Cartoon

This has been a somewhat heavy-handed report thus far—let's end on a lighter note. The cartoon below first appeared in the May 10, 1958 issue of the *New Yorker* and is reproduced with the permission of that magazine. We were quite taken with the cartoon because it seemed the essence of creativity to make something out of nothing. Alan Dunn, who drew (?) it tells us that it has come to be called "The Anti-Cartoon."

—*The Editors*

"All right, Dr. Heisenberg, you've finally achieved the annihilation of matter by anti-matter. Now what?"

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Coming Features in NUCLEONICS

Next Month

Pulse Shaping
in Nuclear Spectrometry
Well Logging—A Review
Radiation Processing of Foods
in Great Britain
Buyers' Guide

Later Months

Critical Facilities
Magnetic Tape Recording
and Nuclear Instumentation
Paramagnetic-Resonance
Studies of Radiation Damage

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N.S. Savannah Progress Report:

Checking the concentricity of the outside and inside diameters and the machined surface on top of giant forging for N.S. Savannah reactor vessel.

B&W Completes 22-Ton Bolting Flange For World's First Nuclear Powered Merchant Ship

This huge bolting flange is part of the vital seal for the reactor vessel of the world's first nuclear powered merchant ship—the N.S. Savannah. Recently completed at B&W's Barberton Shops, the flange is a forged ring weighing approximately 44,500 pounds—over 10 ft in diameter and 2½ ft thick. Specifications called for stainless steel cladding and, despite its great size and weight, *precision tolerances of .005 in. linear and 0° - 30′ angular.* It contains tapped holes into which closure head studs are installed for retention of a formed hemispherical 9-ft diameter head. The completed reactor vessel, of which this precision-built flange is an important part, will stand nearly 27 ft high, and is designed to operate at 2000 psig at a temperature of 650 F.

The experience, skills and facilities developed to produce heavy equipment for the steam generating, petroleum, pulp and paper and process industries have earned B&W a position of leadership as manufacturers of heavy nuclear components. The precise tolerances required present new and unusual manufacturing problems—but problems which are being successfully solved by B&W's skilled engineers and craftsmen.

For nuclear components—or complete nuclear power systems—consult The Babcock & Wilcox Company, 161 East 42nd Street, New York 17, N. Y.

BABCOCK & WILCOX

BOILER DIVISION

NC-101

another

CANADAIR

nucleonic

ACHIEVEMENT

Above
Precision winding of a coil section for the Beta-ray Spectrometer constructed by CANADAIR for Atomic Energy of Canada Limited, at Chalk River, Ontario.

At right
Beta-ray Spectrometer being prepared for shipment.

CASB-NU 24 UST

Canadair's Nuclear Division has successfully applied its engineering and development facilities to the design and construction of the Coils for the generation of the magnetic field in a large Beta-ray spectrometer recently delivered to Atomic Energy of Canada Limited. The spectrometer is used to determine the energy spectrum of Beta-rays emitted from radioactive sources. The large source area, good resolution and high transmission of this $\pi\sqrt{2}$, iron-free, double-focusing spectrometer provide the opportunity of making measurements not previously possible in the field of Beta-ray spectroscopy.

The comprehensive range and accuracy of this spectrometer are in large part the result of adherence to extremely close dimensional tolerances by Canadair's team of nuclear scientists and engineers. Moreover the electrical insulation requirements demanded rigorous control of environment and workmanship.

Canadair designs and manufactures reactors and their components, as well as specialised physics instruments to most exacting specifications: its nuclear division is always available for advice on problems and invites your enquiries.

Write P.O. Box 6087, Montreal, P.Q. for the booklet "CANADAIR IN THE FIELD OF NUCLEONICS".

Nuclear Division

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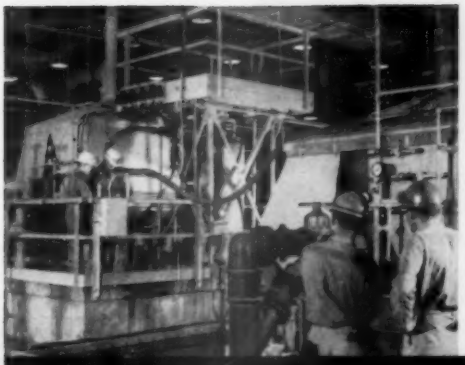


At Mallory-Sharon's large-scale sponge plant *in Ashtabula, Ohio, zirconium is produced by an exclusive low cost sodium reduction process, contributing importantly to the recent price reductions.*

NEW ZIRCONIUM PRICE SCHEDULE

Reactor-Grade (hafnium-free)	Over 500 #	100 # to 500 #	Less than 100 #
Sponge	$6.00 per lb.	$6.50 per lb.	$7.00 per lb.
Chunklets	$6.25 per lb.	$6.75 per lb.	$7.25 per lb.

Prices quoted are for shipments in the U.S.A.

Prices on commercial grade zirconium and on special low Brinell reactor-grade sponge are available on request.

PRICES SHARPLY REDUCED

ON REACTOR-GRADE Zirconium

Mallory-Sharon announces new lower prices on Zirconium sponge and chunklets . . . Mallory-Sharon, world's largest integrated producer of reactive metals, now offers the benefits of substantially lower zirconium prices to commercial builders of nuclear reactors. Price reductions affect both zirconium sponge, a granular material, and zirconium chunklets, non-pyroforic metallic globules which are melted from sponge.

Equally important, commercial users of reactor-grade zirconium will benefit from lower prices on mill shapes.

These lower prices result from the successful operation of Mallory-Sharon's new large-scale sponge production facilities, and the use of its exclusive sodium reduction process. They are also solid evidence that Mallory-Sharon's continuing research is aimed not only at improving quality, but in reducing costs to promote broader use of the newer reactive metals.

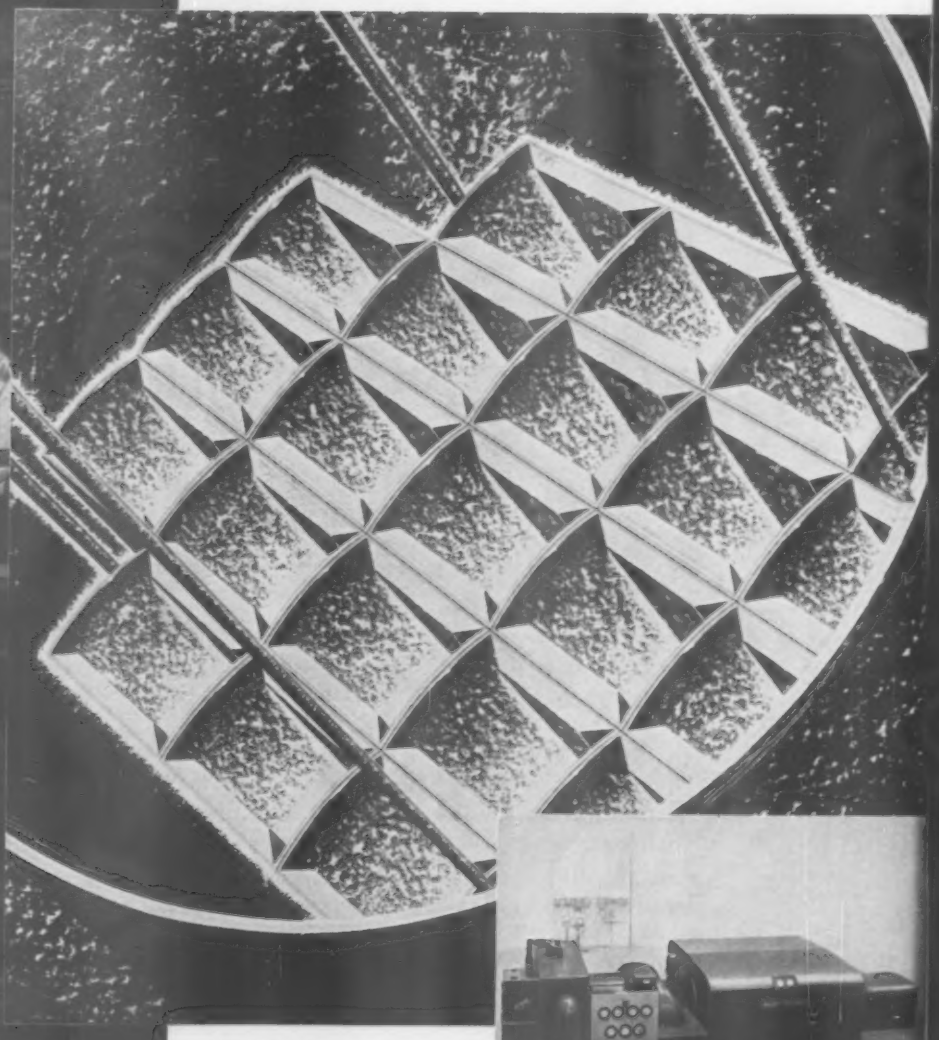
For further information on both Mallory-Sharon reactor-grade and commercial grade zirconium, write for new booklet — *Technical and Application Data on Zirconium.*

MALLORY SHARON

MALLORY-SHARON METALS CORPORATION • NILES, OHIO

Integrated producer of Titanium • Zirconium • Special Metals

NUCLEAR



Reactors

Steam Turbine Generators

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ALLIS-CHALMERS

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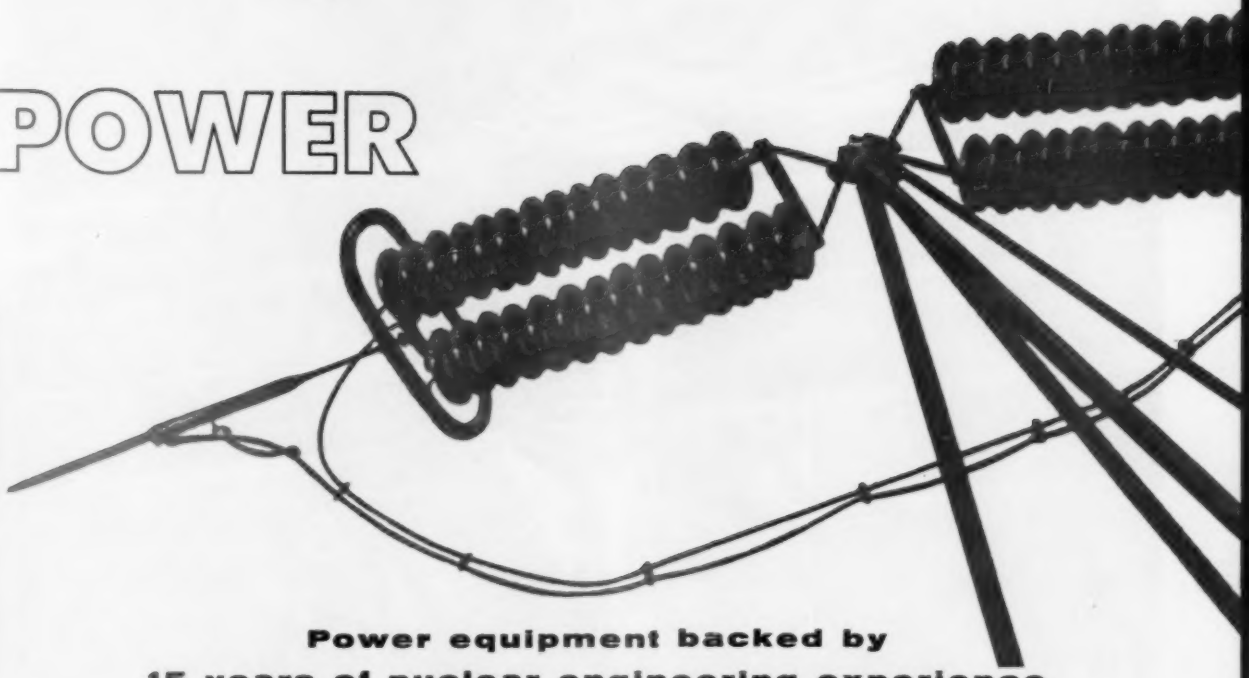
POWER



Power equipment backed by 15 years of nuclear engineering experience

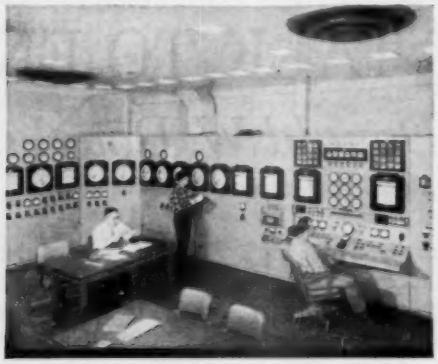
ALLIS-CHALMERS development of nuclear reactors and allied equipment is a logical outgrowth of 75 years of building basic power equipment.

With nuclear experience dating back to the Manhattan Project, facilities, engineering, and production skills are being utilized to produce nuclear power equipment with the same high standards that identify A-C steam turbine generators, condensers, pumps, water conditioning equipment, control, switchgear, breakers, and transformers.

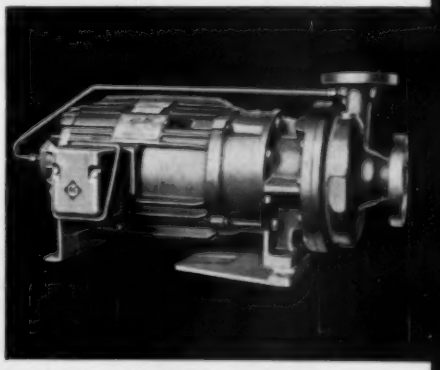
Allis-Chalmers is now engaged in the design and will construct a 66,000-kilowatt nuclear power plant* for the Northern States Power Company in cooperation with ten other electric companies.

Equipment and engineering for all nuclear power plant needs . . .

Condensers



Control and Switchgear



Nuclear Pumps

ALLIS-CHALMERS

*A model of a nuclear power plant using a Controlled Recirculation Boiling Reactor with nuclear superheater will be featured in the Allis-Chalmers exhibit in the United States Exhibition Area, Geneva Atoms for Peace Exhibition.

STRAIGHT TALK TO ENGINEERS

from Donald W. Douglas, Jr.

President, Douglas Aircraft Company

You may wonder what the future holds for the engineer who decides to build his career in the aircraft/missile industry.

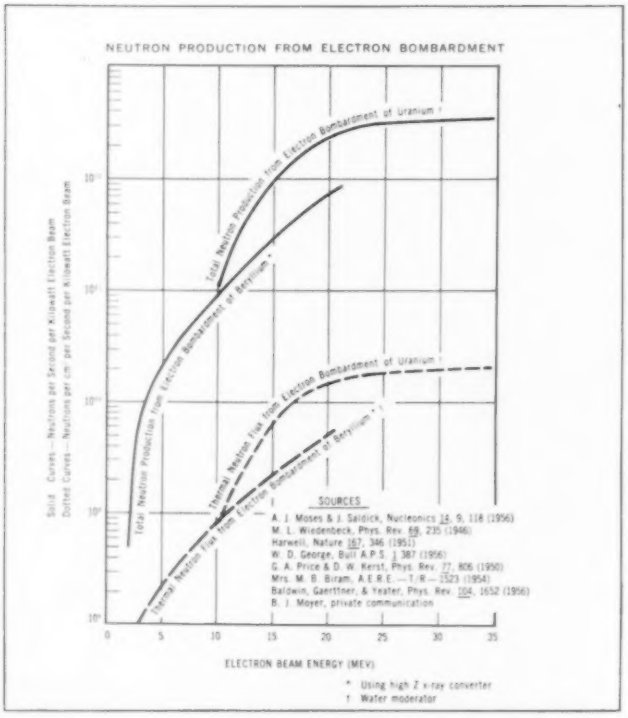
In terms of permanent demand, this industry probably requires a greater proportion of engineers to total personnel than any other. Here at Douglas we are now employing more engineers than we did during World War II.

In regard to professional standing, the aircraft/missile industry deals always with the latest state of the art in every engineering and scientific specialty involved. Its engineers are in one of the best informed and highest prestige fields in their profession.

Whatever your present activity, if you decide to move into aircraft, missile and space technology, we would like to talk with you.

Please write to Mr. C. C. LaVene,
Douglas Aircraft Company, Box L-620
Santa Monica, California

arco APPLIED RADIATION news


NEUTRON PRODUCTION FROM ELECTRON BOMBARDMENT
Total Neutron Production from Electron Bombardment of Uranium †
Total Neutron Production from Electron Bombardment of Beryllium *
Thermal Neutron Flux from Electron Bombardment of Uranium †
Thermal Neutron Flux from Electron Bombardment of Beryllium *
Solid Curves — Neutrons per Second per Kilowatt Electron Beam
Dotted Curves — Neutrons per cm² per Second per Kilowatt Electron Beam
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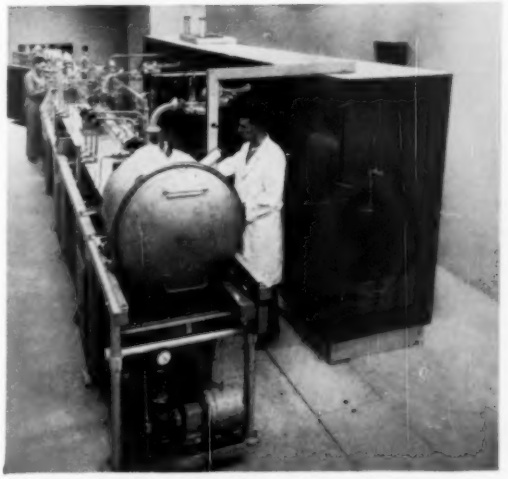
Baldwin, Gaerttner, & Yeater, Phys. Rev. 104, 1652 (1956)
B. J. Moyer, private communication
ELECTRON BEAM ENERGY (MEV)
* Using high Z x-ray converter
† Water moderator

Pulsed neutrons from Linear Electron Accelerators

Traveling wave linear electron accelerators are intense sources of fast and thermal neutrons for measuring neutron cross sections and reactor parameters. Extremely high peak power capabilities make practical the production of neutrons at peak rates on the order of 10^{17} per second. Average yields in the 10^{14} range are practical. High energy electrons and bremsstrahlung, generated through interconversion of accelerator targets—a process requiring only a few minutes, permit research in nuclear chemistry, solid state physics and radiation chemistry. Hence, linear accelerators support broad research programs in the nuclear sciences.

Peak Neutron Yields—10^{17} per second during pulse

High energy photo neutron and photo fission reactions are among the most efficient neutron-producing reactions. Both the efficiency of bremsstrahlung production and the average energy of the bremsstrahlung spectrum increase with the energy of the primary electron beam. Hence, linear electron accelerators, capable of both high beam energy and high power, are intense sources of fast neutrons.



General Atomic's 2-32 Mev, 4 kw ARCO Linear Electron accelerator.
Photo courtesy General Atomic Division of General Dynamics Corporation.

As shown by the accompanying graph, a one kilowatt, 30 Mev linear electron accelerator with a uranium target will generate an average of 3×10^{12} neutrons per second. Since linear accelerators are pulsed, peak neutron yields during a pulse are on the order of 10^3 times the average. Consequently, a 30 kilowatt, 30 Mev accelerator produces neutrons at a peak rate of approximately 10^{17} per second. In conjunction with a subcritical neutron multiplying assembly, even higher yields are practical.

Photo fission reactions yield the characteristic fission energy spectrum; monoenergetic neutrons are obtained by time-of-flight techniques, and thermal neutrons by conventional thermalizing methods.

Electrons and Gammas permit diverse research programs

High linear accelerator gamma yields—several orders of magnitude greater than attainable from betatrons—facilitate study of photo nuclear reactions. High energy electrons and gammas available from the accelerator are useful for research in solid state physics. And intense electron pulses make possible study of free radicals and other short-lived chemical species induced by ionizing radiation. Consequently, a single ARCO traveling wave linear accelerator supports a comprehensive program of nuclear research.

Write for Information

Applied Radiation Corporation specializes in the development and manufacture of electron and positive ion accelerators. Built or under construction are linear electron accelerators ranging in average electron beam power to 25 kw and in electron beam energy to more than 70 Mev. We will be happy to supply detailed data on ARCO accelerators and on accelerator-produced radiations. Write Department N-10.

High energy radiation for research and processing

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Traveling Wave Linear Electron Accelerators
Positive Ion Linear Accelerators
Precision Magnets
Specialized High Vacuum Systems
High Power Klystrons, Power Supplies, Modulators
Linear Accelerator Irradiation Centers—Walnut Creek, California & Rockford, Illinois

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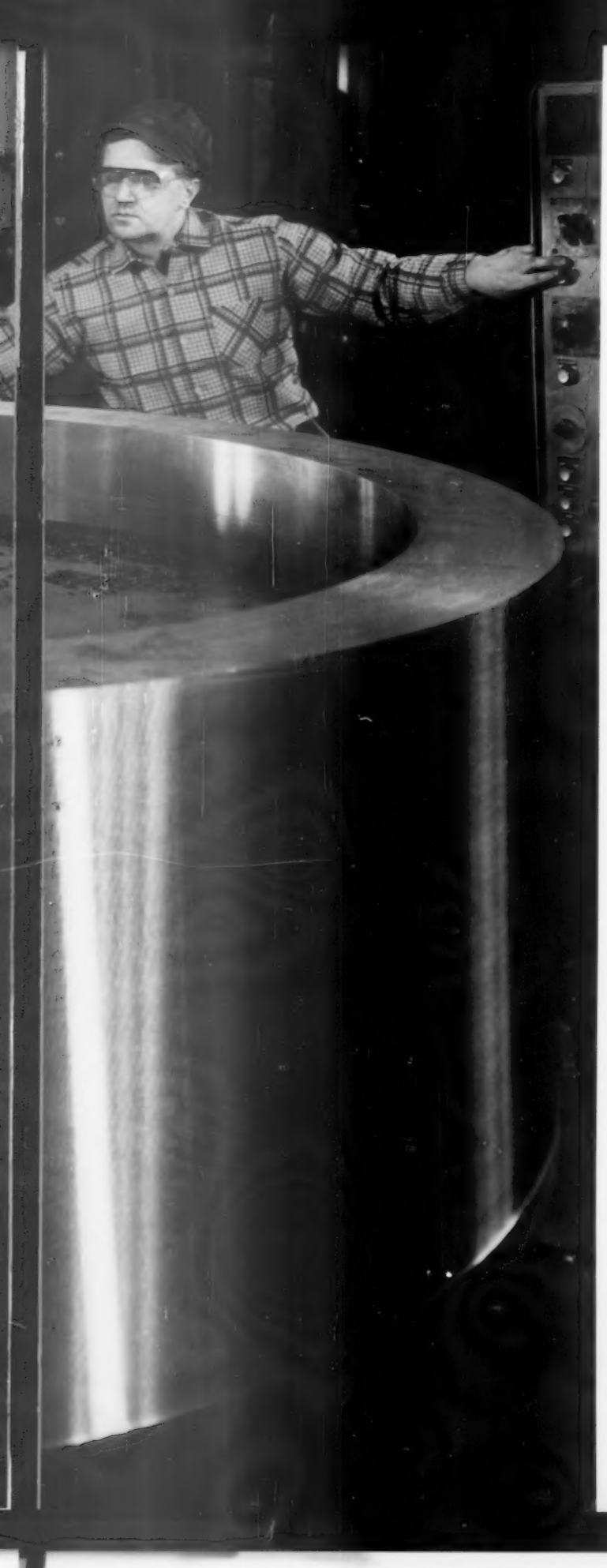

12 tons of forged steel for Yankee fission

The picture shows a steam generator tube sheet forging (one of four) destined for a 134,000-KW nuclear-fueled power plant owned by the Yankee Atomic Electric Company, in Rowe, Massachusetts.

It's a $50-million plant that uses a pressurized water reactor. The USS Quality Forging tube sheet is 85″ in diameter by 26 7/16″ thick. Some 1600 holes will be drilled through the forging longitudinally, and in these holes will be placed stainless steel tubes which will carry high pressure, high temperature main coolant water.

The forged tube sheet is made from carbon steel with a pinch (.057%) of vanadium in it. Starting from the raw ingot, it was heated, forged, rough machined, normalized, tempered, rough machined again, then quenched and tempered. It received a great variety of tests along the way—including several ultrasonic tests. The forging, as shipped, weighed 25,500 pounds.

Nuclear power plant designers have known from the beginning that it is extremely important to use highest quality components. That's the reason why they come so often to United States Steel for its justly famous USS Quality Forgings. And although the one shown here is not complicated, the Forgings Division of USS Homestead District Works has produced a great many complex forgings in everything from carbon to stainless steel, including discs, tapered domes, flanges and cylinders of all types.

No matter what kind of a forging you need, isn't it a good feeling to know that the men who will make it have a solid background of experience? We'd appreciate your inquiries or requests for our free folder on USS Nuclear Forgings. Just write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS is a registered trademark

United States Steel Corporation – Pittsburgh
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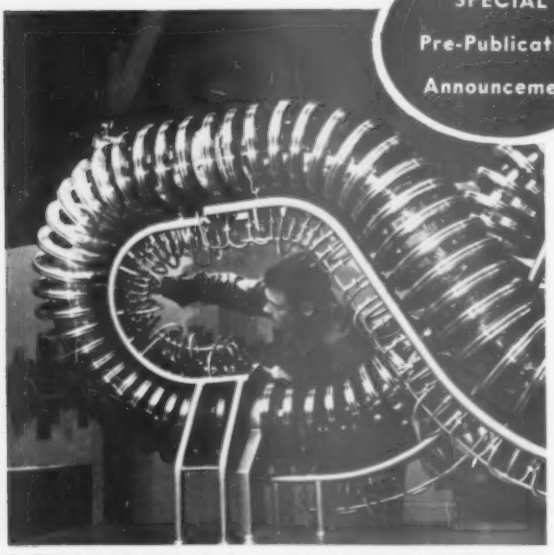
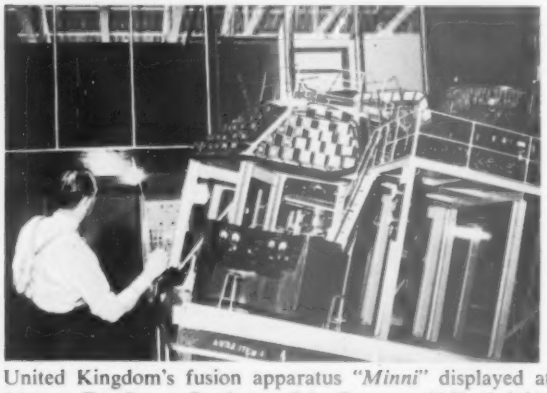
United States Steel



Stellarator developed for producing controlled thermonuclear reaction. The exhibit demonstrates how to confine deuterium gas in tube. *(U.S. exhibit, 'Atoms For Peace' Conference, Geneva, Switzerland.)*



United Kingdom's fusion apparatus *"Minni"* displayed at "Atoms For Peace Conference" in Geneva. *(U.K. Exhibit, 'Atoms For Peace' Conference, Geneva, Switzerland.)*

SPECIAL
Pre-Publication
Announcement

Proceedings of the SECOND INTERNATIONAL CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY

Geneva: September 1st — 13th, 1958

The United Nations edition in English will be the ONLY COMPLETE AND OFFICIAL EDITION of the Conference Proceedings

The English Edition is expected to consist of 33 volumes (approximately 500 pages each) and will comprise the COMPLETE OFFICIAL PROCEEDINGS (more than 2,100 scientific papers and discussions).
First volumes available by November, 1958; set completed by July, 1959.
Transportation charges will be borne by UN for Pre-paid Full Set Orders.

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- Basic physics
- Basic chemistry
- Biology and medicine
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- Thermonuclear developments
- Possibility of controlled fusion
- Raw materials
- Production of nuclear materials
- Research and power reactors
- Reactor technology
- Production and uses of isotopes
- Training in nuclear sciences

PRE-PUBLICATION PRICE FOR FULL SET:
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UNITED NATIONS
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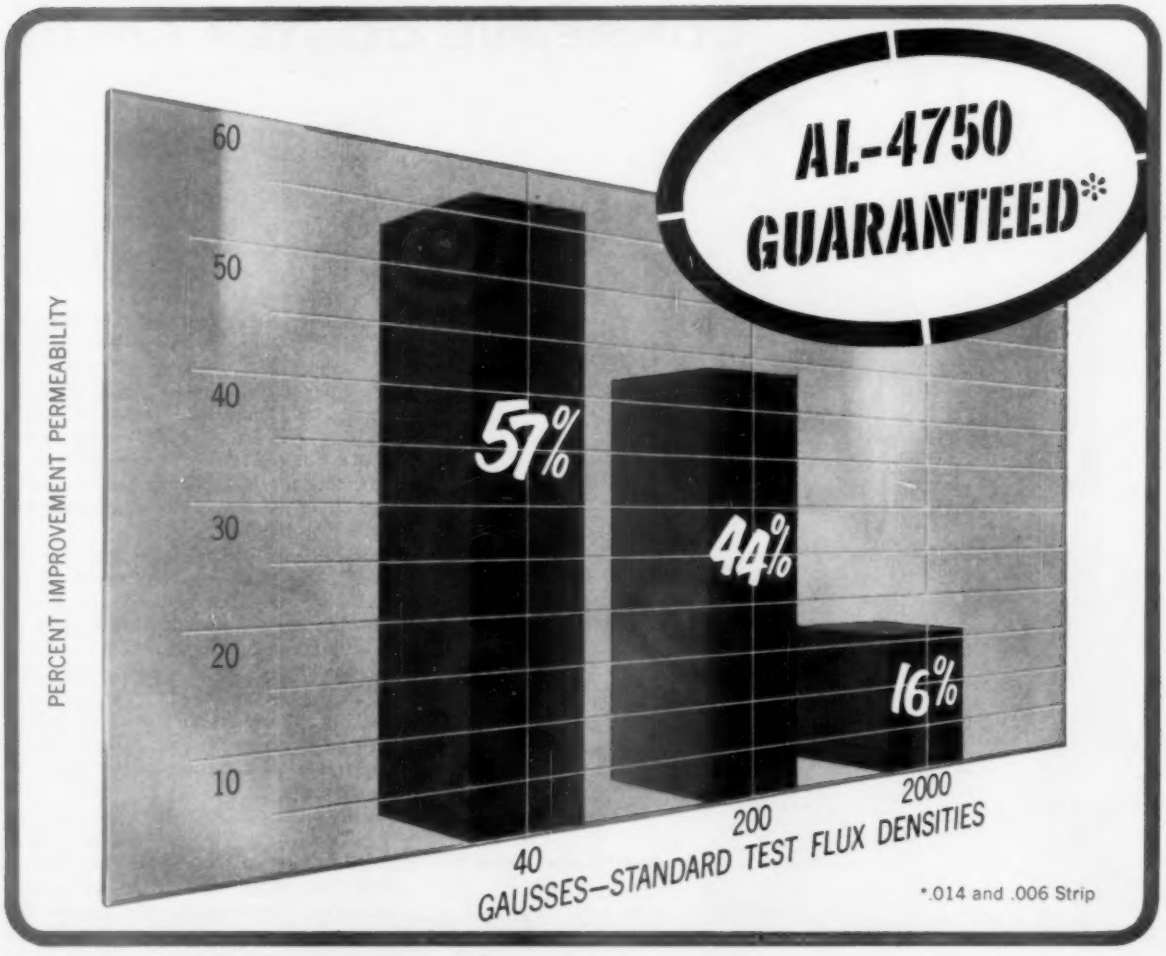
Scientist shows visitor the experimental boiling water reactor which can provide up to 5,000 kw of electricity to help meet the world's anticipated power needs. *(U.S. exhibit, 'Atoms For Peace' Conference, Geneva, Switzerland.)*

Experience**—the added alloy in **A-L Stainless, Electrical and Tool Steels



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AL-4750 nickel-iron strip now has higher permeability values than ever before . . . and the new, higher values are guaranteed. For example, using the standard flux density test, at 40 induction gausses, AL-4750 now has 57% higher permeability than in the past. And permeability values are guaranteed.

This guaranteed permeability means greater consistency and better predictability for magnetic core performance . . . permits careful, high performance design.

The improvement in AL-4750 didn't just happen. It is the result of Allegheny's electrical alloy research and production program in nickel-bearing steels. A similar improvement has been made in AL Moly Permalloy. And research is continuing on silicon steels including AL's famous Silectron (grain oriented silicon steel), as well as on other magnetic alloys.

Another service of Allegheny Ludlum includes complete facilities for the fabrication and heat treatment of laminations. Years of experience in AL's lamination department means that Allegheny Ludlum has encountered and solved most problems common to core materials. This practical know-how is available to all. Call us for prompt technical assistance. Write for blue sheet EM-16 for complete data on AL-4750.

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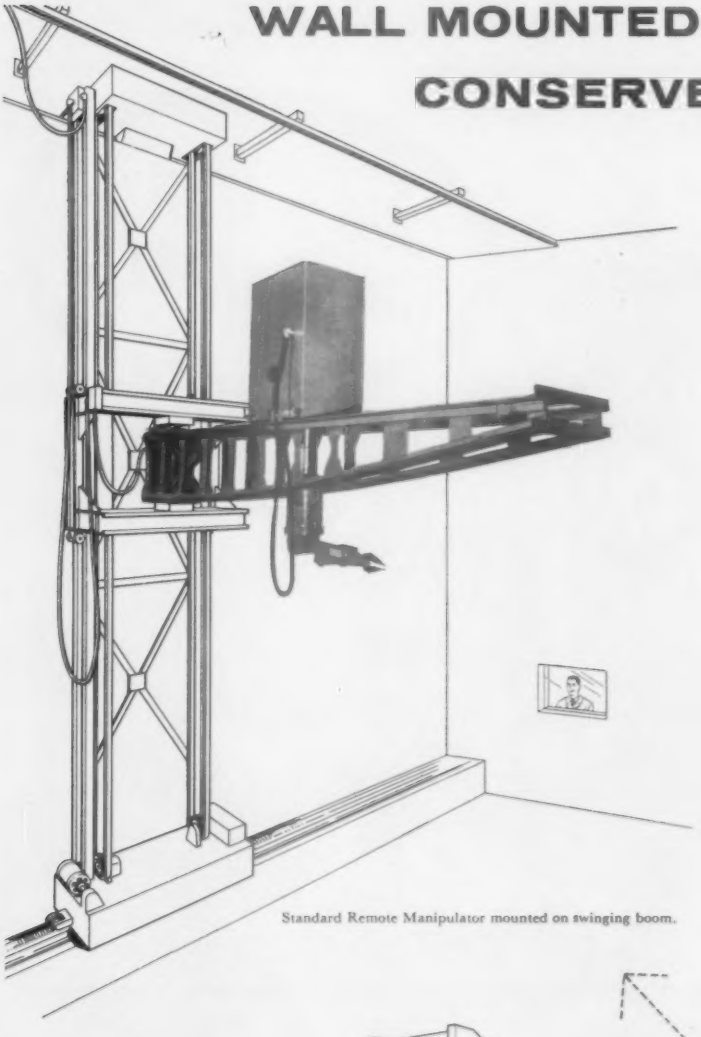
WALL MOUNTED MANIPULATORS CONSERVE COSTLY SPACE



Standard Remote Manipulator mounted on swinging boom.

Wall mounted Mechanical Arms are quickly and easily installed in a variety of ways to overcome unusual "hot" facilities arrangements or restrictions.

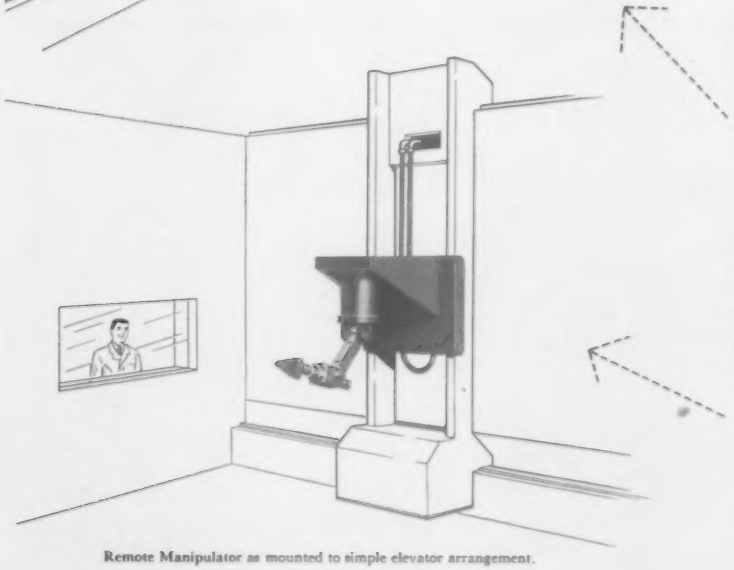
They are specifically designed to fit areas where low headroom or overhead equipment does not permit a horizontal crane bridge mounting.

Pictured are two typical wall installations. The Arm on the swinging boom is especially adaptable to "hot shops" or similar large operational areas. The other—mounted on a vertical track—is ideally suited for cells where large volume coverage is not necessary, or in gas-tight areas where through-wall manipulators cannot be used, or where space limitations are especially confining.

One of these standard units may be the answer to your manipulator needs. If required, they can be adapted to special conditions . . . or a complete custom design can be made to your specifications.

Take advantage of the atomic industry's most experienced source of "hot" materials handling equipment and systems. Whatever your needs, we're ready to give you a complete technical-consultation and design service.

An exciting new booklet will give you all the facts about our complete manipulator line and "hot" materials handling systems —WRITE, WIRE OR PHONE Nuclear Equipment Department, Mechanical Division of General Mills, 1620 Central Avenue, Minneapolis 13, Minnesota. STerling 9-8811.



Remote Manipulator as mounted to simple elevator arrangement.

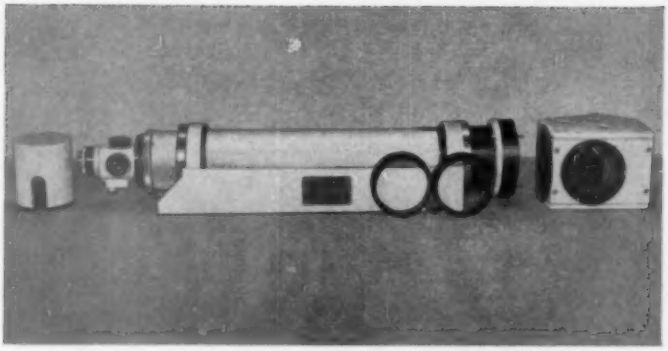
Here's Mechanical Arm mounted on swinging boom. In addition to universal movement of Arm itself, arm carriage travels in and out on boom and moves vertically and horizontally on upright bridge along wall. Exact vertical positioning of Mechanical Arm is provided by telescoping hoist. A telescoping boom is an optional arrangement for more extended coverage. All movements are precision controlled from remote console.

In this smaller installation, the Arm's shoulder housing is attached to an elevator. Arm performs full range of movements under precision control from remote console.

Nuclear Equipment Department
Born with the nuclear age—a decade ago

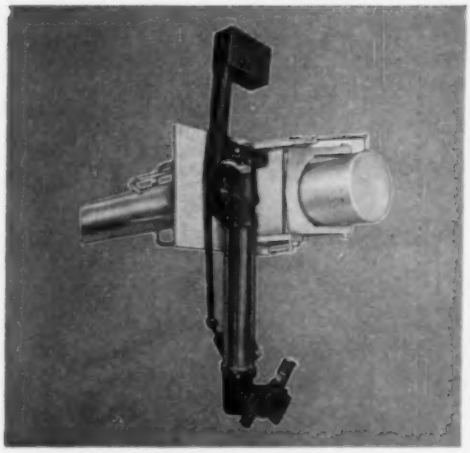
MECHANICAL DIVISION

General Mills



Problem To align radar antennas with extreme accuracy.

Solution Kollmorgen 30X Collimator.
Measures within a pencil's width at a mile.



Problem Remote viewing in the presence of harmful radiation, heat, pressure, water or toxic gases.

Solution Kollmorgen Wall Periscopes with non-browning optics, corrosion-resistant materials, 180° scanning.

Kollmorgen instruments like these are bridges between the eye and the invisible.

The various instruments on this page all have one purpose in common—they allow the observation and measurement of objects which it would otherwise be impossible to see in detail. In bunkers, under water, in the absence of light, in the presence of radioactivity and under many other adverse conditions, Kollmorgen remote viewing instruments have brought the eye of the observer to the heart of his problem.

A letter to us with a simple sketch illustrating your remote viewing problem will place one of America's most respected and versatile designers and manufacturers of optical instruments at your service. For more information write Department 110.

Problem Detailed, long-range observation at sea under varying weather conditions.

Solution Kollmorgen 20X, 120 Ship Binocular. Wide, bright field. Hermetically sealed, super lightweight.

Problem Internal inspection of inaccessible areas of tubing, long bores, machinery, engines, aircraft structures.

Solution Zeiss-Kollmorgen Self-illuminating Borescopes. Diameters from .100", lengths to 45 feet. Bright, clear field.

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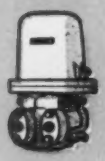
Indicating Motion-Balance Transmitters
...for flow, pressure, and level

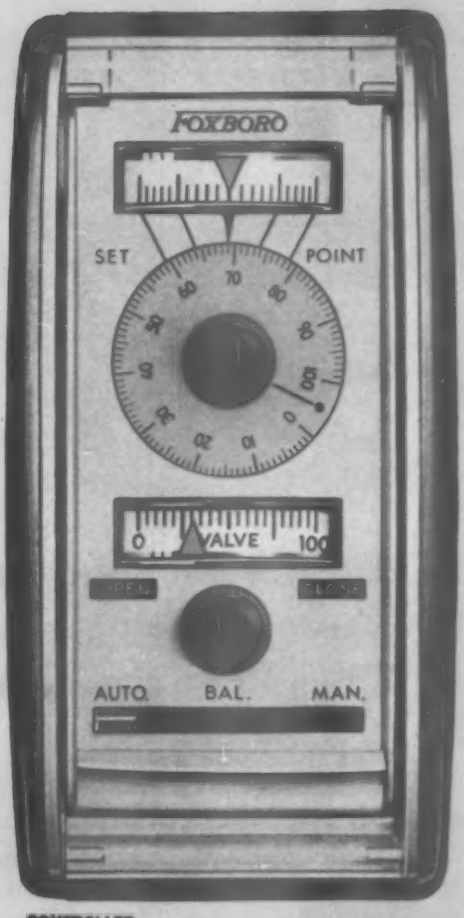


Low Displacement Force-Balance Transmitters
...for flow, pressure, and level

Thermocouple and Resistance Bulb Converters
...magnetic amplifiers...no vibrators
...no mechanical rebalancing

Displacer Level Transmitters
...force-balance for simplicity

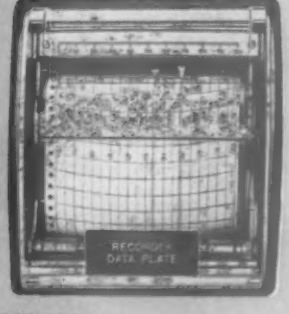
Control Valves
...electro-pneumatic and electro-hydraulic actuators



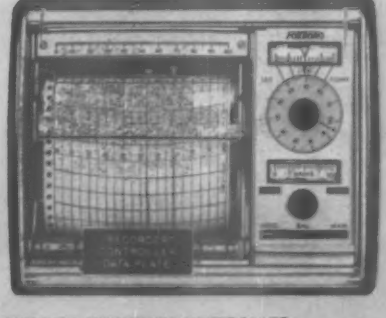
CONTROLLER
The Electronic Consotrol Controller (shown 4/5 actual size) concentrates all control and supervisory functions in one slim 3 x 6 inch case. Controller operation is entirely independent of recorder.

FOXBORO Electronic

REG. U.S. PAT. OFF.



RECORDER
Electronic Consotrol Recorders (shown ¼ actual size) use a simple, powerful pen motor which can be operated directly from transmitter signal without amplification. Available in 1 and 2 pen models.



COMBINED RECORDER-CONTROLLER
Electronic Consotrol housing design permits unequalled flexibility in panel arrangement. Recorders and controllers can be mounted separately in individual housings—or enclosed in a compound unit. Regardless of mounting, either unit pulls out independently.

for the first time... the 100% solid state electronic system!

- thermocouple and resistance bulb converters – using magnetic amplifiers
- choice of force-balance and motion-balance transmitters
- long time-constant tubeless controllers

Consotrol Instrumentation

Electronic Consotrol* Instrumentation—the most complete and advanced family of electronic-operated measurement and control instruments available today! That just begins to describe Foxboro's dramatic new advance in instrumentation. ✓ ✓ ✓ Foxboro electronic transmitters, indicators, recorders, control stations, computing stations, valve actuators and other final operators cover every function in the control loop. All are linked by a d.c. current signal. All are completely tubeless. Even thermocouple and resistance-type systems no longer require vacuum tubes. ✓ ✓ ✓ Electronic Consotrol systems convert temperature, pressure, flow, level measurement, etc., to a proportional signal at the transmitter. Transmission to a remote control station is instantaneous—using an electronic motion-balance or force-balance transmitter. Designs are available for both hazardous and non-hazardous areas. ✓ ✓ ✓ Electronic Consotrol Instrumentation heralds a whole new era in process control engineering. Write Foxboro today for the new 32-page Catalog 21-10 which gives full details. The Foxboro Company, 6210 Neponset Ave., Foxboro, Mass., U.S.A.

*Reg. U.S. Pat. Off.

rigid specifications

Tension tests are required to be made at room temperatures and at 670° F. The following minimum physical properties shall be met:

At Room Temperature:

TS	YS	EL	RA	CHARPY V-NOTCH
70,000	30,000	45	50	50

At 670° F. the minimum tensile strength shall be 51,000 p.s.i. and the minimum yield strength 18,300 p.s.i.

Rejection

Each casting that develops unacceptable defects during shop working or fails to conform to all of the requirements of these specifications shall be rejected. No repair by welding or other means will be permitted.

Radiographic Inspection

(a) Paragraph S5 (a) of the Supplementary requirements of ASTM-A 362-52T.

(b) All castings shall be radiographed 100% and shall conform to ASTM-E7 1-52, Class 2 quality, except as modified by these specifications.

(c) The manufacturer shall establish a positive system of identification of the X-ray plates which shall be subject to approval by the inspector. This system shall guarantee complete coverage by radiographing and provide for positive identification between the plate and the subject.

Inspection of Penetrants

All castings shall be subjected to inspection by fluorescent penetrants or penetrating dyes both inside and out. All cracks, porosity, or flaws revealed as a result of the Dye Penetrant Test shall be due cause for rejection of the casting.

All cast pipe shall be hydrostatically tested to 5,900 p.s.i. and held at that pressure for 20 minutes with zero pipe leakage. Each length of pipe shall be hydrostatically tested at the manufacturer's plant.

The 304L stainless steel shall conform to the following ladle analysis:

Carbon	.03 max.		
Manganese	1.50% max.		
Phosphorous	.03% max.		
Sulphur	.03% max.		
Silicon	2.00% max.		
Chromium	18.00	-	21.00%
Nickel	8.00	-	11.00%

Pipe: All pipe of the following sizes shall be centrifugally cast stainless steel as per ASTM-A 362-52T, except as modified by these specifications:

16" - Sch. #160
12" - Sch. #160
10" - Sch. #160
8" - Sch. #140

All pipe shall be machine finished to 125 micro-inch interior and exterior.

for nuclear piping met by U.S. PIPE metal mold process

Centrifugally Cast Stainless Steel Solves Many Piping Problems

Combinations of temperatures, pressures and corrosive conditions never encountered before: these are among the piping problems that must be overcome by the men who design the nation's nuclear power installations.

Stainless steel centrifugally cast pipe provides many of the answers. Study the specifications at the left . . . specifications demanded of stainless steel pipe on a recent job for Paul Hardeman, Inc., Los Angeles, California. This pipe is being used for heavy duty, high pressure, elevated temperature service in the primary piping system of the SPERT-III Reactor at the U. S. Atomic Energy Commission's National Reactor Testing Station near Idaho Falls, Idaho. The Stearns-Roger Mfg. Company, Denver, Colorado, is the architect-engineer on this project. A complete tabulation of the actual test data obtained on this pipe and to this specification is available upon request.

U. S. Pipe is headquarters for metal mold centrifugally cast alloy and stainless steel pressure pipe over a wide range of special and standard analyses—in large and small quantities—and to individual specifications.

If piping of the type described above is the bottleneck in your nuclear power planning, write and outline the problem.

SIZE RANGE AND COMPOSITION FLEXIBILITY

Outside Diameter—6" to 50"

Wall Thickness—⅜" and up

Length—Up to 16'

Types of Stainless—All Standard AISI and ACI grades of ferritic and austenitic stainless, including No. 20 Alloy, 17-4 P H, 17-7 P H and E.L.C. grades.

UNITED STATES PIPE & FOUNDRY CO.

Steel and Tubes Division

STEEL & TUBES U.S. PIPE DIVISION

BURLINGTON, NEW JERSEY

SALES OFFICES: LOS ANGELES, SAN FRANCISCO, CHICAGO, ST. LOUIS, COLUMBUS, PITTSBURGH, HARTFORD, BURLINGTON

Progress in POWER GENERATION

Innovation and refinement in nuclear power reactors will be the most significant development in electric power generation during the next ten years.

In that time, utilities engineers through much of this country will routinely weigh the advantages of nuclear versus conventional generating stations. And increasingly, the nuclear station will be specified.

	DESIGNATION	PURPOSE	STATUS	FUEL	COOLANT	MODERATOR	REFLECTOR	POWER	SPECIAL FEATURES
swr	Steam Water Reactor	Power generation.	Under study by NDA and East Central Nuclear Group	UO_2 (natural uranium)	Steam (H_2O)	D_2O	D_2O graphite	200,000 KWe	Direct cycle. Produces superheated steam approximately 1050° F., 2000 psi. High cycle efficiency, low fuel cost.
sdr	Sodium Deuterium Reactor	Power, reactor prototype to demonstrate feasibility of system.	Part of AEC Power Reactor Demonstration Program. Conducting mechanical and chemical tests on design features. Preparing preliminary design.	Slightly enriched uranium	Sodium	D_2O	D_2O	10,000 KWe	Combines best moderator with best coolant in single system yielding high efficiency steam cycle conditions. Potential utilization of natural uranium fuel in higher powered version.

Two NDA reactors for progress in power generation.

Through its work for Government and industry during the past ten years, NDA has developed a highly qualified reactor team. NDA reactors aim at the delivery of steam at temperatures and pressures suited to modern turbines. Emphasis is placed on advanced technology using high temperature-low pressure coolants, high neutron efficiency moderators and the use of natural or low enrichment uranium fuel.

NDA's team consists of almost 400 reactor scientists, engineers and supporting personnel with a single business—design and development of high performance nuclear reactors. Inquiries are invited from electric companies or study teams.

a complete reactor company

NDA — NUCLEAR DEVELOPMENT CORPORATION OF AMERICA

WHITE PLAINS, N.Y. TEL. WH. 8-5800

NDA EUROPE 31, Rue du Marais, Brussels, Belgium

ROUNDUP of Key Developments in Atomic Energy

AEC Off on Ambitious Program to Speed Radiation Use

On July 30 this year, AEC shipped its 500,000th curie of radioactive material from the Oak Ridge National Laboratory. While this milestone was a development of some historical significance, it was hardly the most important event of 1958 to AEC's isotope people. That event came less than a month later when President Eisenhower signed a bill making $4-million available to the AEC Office of Industrial Development for the first year of an ambitious program to promote the use and production of low- and high-level radiation.

The sum of $4-million is but a fiscal snowflake in the federal budget blizzard of $80-billion (both amounts to be spent before the end of June next year). This particular snowflake, however, will be carefully dropped on a downhill slope, where, it is hoped, it will pick up neighboring flakes and emerge at the bottom of the hill as a huge snowball, surviving long after the other flakes have melted away.

The radiation program is the first formal attempt by AEC to do what it has been doing for several years in the reactor field—prime the pump of research and development to hasten commercial utilization. AEC expects to get much more priming action out of its radiation dollars, however, because they will be spent to develop uses for entire industries and groups of industries. In addition, virtually all of the work will be done by private industry.

"We're going to put money into the field to develop technology," was the flat statement of an AEC official. "We're going to let industry do the work and we're going to support it financially."

Program Direction

The program is under the direction of Paul Aebersold, assistant director of the Office of Industrial Development for isotopes and radiation, and his deputy, Gene Fowler. Under them are Paul Blaetus, chief of the isotope technology branch; Joseph Machurek, chief of the isotope production and radiation branch; and Oscar Bizzell, chief of the isotope applications branch.

The budgets of each of these branch chiefs for the first year of the program's operation show better than anything else how the program will work as it moves simultaneously in three directions:

- The technology branch has been given $1.1-million to establish a special AEC course at Oak Ridge in industrial isotope applications, to encourage applications for training programs in colleges and universities, and to promote the awareness of isotope potential within the commercial public.
- The isotope production and radiation branch has been given $1.1-million to encourage, through a series of research and development contracts with private industry, the production of radioisotopes by industry and employment of massive radiation sources commercially.
- The isotope applications branch has been given $1.8-million to support another series of contracts aimed at developing new uses and enlarging existing uses of radioisotopes.

In point of time, the contracting program has been divided into two phases: 1. AEC-supported surveys of radiation potential, under a series of contracts which were awarded even before Congress appropriated program funds (*see table, p. 22*); and 2. AEC-supported development work under a series of contracts to be awarded this year and in ensuing years of the program to projects which offer the broadest commercial yields. Some 40–50 industry proposals were submitted to AEC even before it could issue a formal invitation late last month.

Training

The ORINS course was established because a serious problem in the development of commercial radiation has been the lack of trained personnel, especially technicians in general industry who might put radiation to work in their fields if given only a short exposure to application techniques. The prototype course, designed specifically to meet this need, will be given at the Oak Ridge Institute of Nuclear Studies beginning Feb. 9 (for six weeks) and at regular intervals thereafter.

Also under study is an AEC request to colleges and universities to offer summer institutes patterned after the ORINS prototype course, plus a grant program similar to that now in existence for reactor training to assist college-level institutions to purchase radiation training equipment.

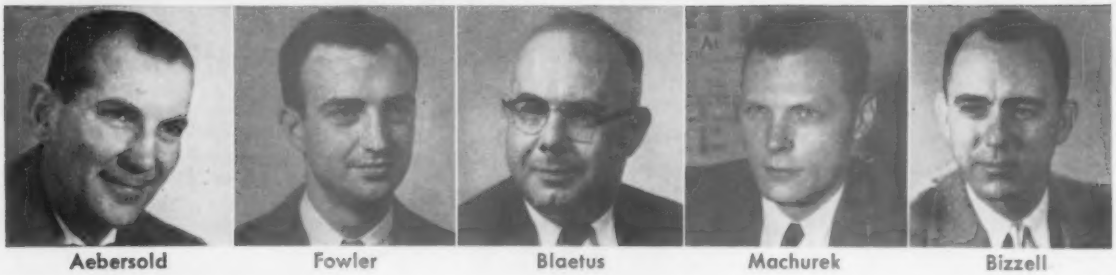
To get radiation technology across to businessmen, as well as techni-

Reactor program advances, too; 5 concepts involved

September was a big month for the AEC reactor program. There were these developments involving five advanced concepts:

- AEC called a meeting with industry on the outlook for private sponsorship of the advanced gas-cooled reactor (NU, Sept. '58, 155), then issued a formal invitation for proposals (see page 27). AEC officials said they expected at least one reply, possibly more (AEC will build if industry does not).
- AEC received 14 replies to its invitation for design-study proposals covering a "minimum-size prototype" of a heavy-water-moderated reactor using natural uranium; preliminary design must be completed by March 1. Meanwhile, AEC said construction will begin later this year on a component test reactor for the D_2O program; primary function of the facility (at Savannah) will be test of full-scale fuel elements.
- AEC invited design-study proposals covering power stations using advanced versions of pressurized water, boiling-water and organic-moderated reactors—for hypothetical construction in 1960. Bids, due Oct. 15, may be made for all three studies but no bidder will get more than one. Optimum size of station and reactor (or reactors) will be left to bidder.

1. RADIATION PROGRAM LEADERSHIP



Aebersold | Fowler | Blaetus | Machurek | Bizzell

2. PROGRAM CONTRACTS TO DATE

	Subject	Contract Expires*	Amount ($)
General			
Emerson Radio (CEM group)	industrial radiation survey	April '59	$ 86,847
National Industrial Conference Board	isotope economics	March '59	75,000
W. H. Johnson Associates	industrial applications, low- and high-level	April '59	89,000
Stanford Research Inst.	medical applications	April '59	60,000
Radioisotope applications			
Armour Research Foundation	X-ray sources	June '59	53,000
Tracerlab	gas analysis	June '59	49,000
General Atomic	isotope production	June '59	61,000
Radiation Applications	large fission-product sources	December '59	32,300
Battelle	control systems	June '59	22,000
Nuclear Science & Eng.	industrial appl.	June '59	22,000
High-level			
Atomics International	reactor coolant (sodium) as radiation source	December '58	76,000
		Total	$626,147

* All contract periods begin with June '58 with the exception of NICB which begins May '58.

3. GROUND RULES FOR NEW AWARDS

- **Cost to AEC**
- **Advancement of technology**
- **General applicability to industry**
- **Uniqueness of proposed development activity**
- **Application to key industries where radioisotopes have not been exploited**
- **Specific experience in area of proposed development**
- **Potential contribution to the national economy and welfare**
- **Competence and responsibility of applicant, including organization, experience, facilities and financial responsibility**

cians, the technology branch plans the production of four films on applications and safe handling, and four regional symposia to be presented on college campuses. Two of these have already been scheduled for later this year at Atlanta and Manhattan, Kan. Finally, the first of what may become a series of federal-state meetings is scheduled at Miami, Dec. 3–4, on "The present and potential applications of radioisotopes for Florida industry."

Production

AEC is the sole producer of radioisotopes and it has generally been assumed that this situation will prevail until the first private power reactors bring by-production of these materials in the early 1960's. However, AEC sources disclosed, at least five large industrial firms have been giving serious consideration to isotope production and are presently analyzing the market.

Until private firms do get into isotope production, AEC will maintain and buildup its output to guarantee an adequate supply at the lowest possible prices. The Multicurie Fission Products Pilot Plant which went into operation at Oak Ridge in August was a significant step in this direction. Its ability to produce kilocurie quantities of cesium-137, promethium-147, cerium-144, strontium-90 and technetium-99 has permitted price reductions of as much as 99% for these isotopes (NU, May '58, 27).

The new Oak Ridge facility is essentially a separations plant for the radioactive by-products of reactors operated for power or plutonium production. Through the market-development phase of its radiation program, AEC is seeking to make it economically feasible to build reactors primarily for isotope production—reactors for either single or multiple isotope production.

High-Level Radiation

Perhaps the most exciting aspect

of the new program—in terms of industrial potential—is the plan to accelerate the development of massive radiation sources for heat and/or radiation; a major pioneering effort has been scheduled to develop fabrication techniques for large radiation sources and to define the peaceful applications for high-level radiation. Simultaneously with the award of development contracts with industry, AEC is stepping up its high-level radiation work at both Oak Ridge and Brookhaven.

The high-level effort is concerned primarily with three types of facilities: (a) those, like the Quartermaster Corps' Hi-Fi installation in California, using a multicurie quantity of a single isotope; Hi-Fi will have a cobalt-60 gamma source rated at 2-million curies (NU, July '58, 27); (b) those using the gross fission by-products of commercial reactor operation; and (c) reactors designed for continuous processing of commodities like chemicals, coal.

The first high-level irradiator to be built for the new program—aside from Hi-Fi, which is slated for military food-irradiation duty—has already been funded by Congress ($1.6-million). But AEC would like to see industry build this (and subsequent) irradiators and will attempt to work out a cooperative project wherein AEC contributes some portion of cost or leases space. If no suitable cooperative plan can be arranged the irradiator will be AEC-built; no decision will be made before next spring when a survey of high-level radiation potential by the National Industrial Conference Board will be completed (NU, July '58, 27).

Contracts will be let this fiscal year for development work on both gross fission products and reactors designed for high level radiation and heat. "If somebody comes in the door right now with a good ideal on high-level radiation we are ready to talk business," says branch chief Machurek.

Isotope Applications

The largest slice of the program budget ($1.8-million) has been apportioned to Bizzell's branch for stimulation of isotope use. To put it mildly, as AEC does in its brochure inviting development proposals from private industry: "The known applications of radioisotope techniques have by no means saturated the market . . . "

In reviewing contract bids for isotope development, AEC will look for proposals of broad interest to an industry or segment of an industry, as opposed to those with potentially narrow application. These areas will be explored: 1. control systems engineering; 2. nondestructive testing applications; 3. tracer applications in industrial research and in process control; and 4. activation-analysis techniques.

A few contracts have already been let for isotope development (see table) but the bulk of these awards for this fiscal year will come between now and the end of June.

Hanford Also Active

Independently of the radiation development program being directed by the Office of Industrial Development, AEC is supporting a low- and high-level radiation program at the Hanford Works near Richland, Wash., where the production of plutonium has made fission by-products plentiful.

General Electric, operator of Hanford for AEC, has announced the start of construction on a $1,073,800 radiochemistry building for research and development work on process and separation of these by-products. High-level radiation work (up to 1-million curies) will be done in three cells equipped with mechanical hands and sharing a "super manipulator" which can be moved between cells through specially designed doors at ceiling level.

The facility will also have an underwater storage basin designed for remote transfer of radioactive materials between storage and cells. Construction contractor is B. D. Bohna Co., San Francisco. Operation of the facility will be directed by R. L. Moore, chief of fission-products chemistry.

GE has also put Arthur D. Little, Inc., to work on an exhaustive study of the market for fission products (NU, Apr. '58, 24). The study is in two parts: commercial potential (which is nearing completion) and military potential (just getting started).

AGIP Nucleare Signs Pact with NPPC—Italy's First

A construction contract for Italy's first power reactor—to be built at Latina, 40 mi south of Rome—went to Britain's Nuclear Power Plant Co. last month, three weeks before the SENN announcement (see page 25). NPPC will build a 200-Mw(e), gas-cooled, graphite-moderated reactor for AGIP Nucleare. Completion is due in 1962.

EBWR, CP-5 Power To Be Boosted

Work will start this year at Argonne National Laboratory to increase the operating power levels of the Experimental Boiling Water Reactor (EBWR) and the CP-5 research reactor.

A $1.5-million conversion contract for an increase to 100 Mw(th) in EBWR's power went to Sargent & Lundy last month. Design power is now 20 Mw but the reactor was run up to 62 Mw earlier this year (NU, Apr. '58, 25).

Modifications will include: installation of heat exchange equipment to absorb the 80 Mw of heat which will be surplus to the 20-Mw turbine already in place; heat removal equipment; and a new cooling tower. The 4 × 4-ft core will be replaced by a 5 × 5-ft core of new design. Work should be completed by the end of next year.

Modification of CP-5, increasing its power level from 2 Mw to 10 Mw, will be handled by Shaw, Metz & Dolio under a $500,000 contract. The increase will give CP-5 a larger neutron population for quicker irradiation of materials and greater versatility. Work will include: a concrete building, adjacent to the reactor, housing a storage canal for spent fuel elements and several "hot" caves; new heat exchange equipment within the reactor shell; modifications to the existing cooling tower and construction of a new cooling tower. New fuel elements will go into the reactor before operation at 10 Mw.

France Reaches Decision On U-235; Will Build Plant

France has officially announced its decision to build a gaseous diffusion plant for the production of enriched uranium, though no construction date has been established. A decree declaring construction of the isotope separation plant to be a matter of national urgency was issued last month.

The plant will be built at Pierrelatte, 30 kilometers north of Marcoule, across the Rhone River.

France, starting from scratch, has developed its own process and its own isotope barrier—a teflon-like material. A single test cell has been working successfully at Saclay and a pilot plant with 12 cells has been operating there for several months.

At Geneva, France presented seven papers on its gaseous diffusion process.

Euratom Satisfied with Arrangement Despite Changes; JCAE Ties A Few Strings to Fuel-Guaranty System

Euratom, generally satisfied with its U. S. reactor agreement despite delays stemming from both commissions and omissions of the 85th Congress, began marshalling its electric utility forces last month with an eye to placing reactor orders in the U. S. some time in February.

Before Congress went home late in August, it failed to approve the proposed bilateral agreement between the two governments and made some unilateral changes in the bill authorizing U. S. participation, including some important changes in the fuel guaranty arrangement (NU, Sept. '58, 152).

Euratom officials in Brussels said they were disappointed that the bilateral was not ratified by Congress but indicated they were grateful for the leeway provided by Congress' insistence on a two-year extension of the deadline for two of the six reactors contemplated.

Indeed, a hard look at the program as it stands post-85th Congress makes it clear that the extension will give the program some much-needed breathing space. Following are some of the things which must be done—as outlined by AEC officials—before so much as a reactor groundbreaking takes place:

- The bilateral agreement for cooperation must be submitted to Congress for debate and review early next year. And two leaders of the Joint Committee on Atomic Energy—Sen. Clinton P. Anderson (D-N. M.) and Rep. Chet Holifield (D-Cal.)—have already served notice that the review will be an intensive one.
- No proposal to build under the financial umbrella of U. S. fuel guarantees can be submitted to U. S. and Euratom authorities by the contractors until the bilateral has been approved (March of next year at the earliest, AEC officials estimate).
- No work can commence until a joint U. S.-Euratom board has selected the projects then submitted them to JCAE for authorization on a project-by-project basis. This is the same procedure employed for domestic projects involving government money.

In sum, the architects of this bold program face the same sort of two-way bind in 1959 that plagued their efforts of 1958—a shortage of time and a sometimes-difficult Congress. Between the relatively short period from March to August they will have to invite industry proposals, select and perhaps renegotiate the best, and persuade JCAE to okay them. AEC spokesmen say flatly that none of the first four Euratom projects will meet the target date for operation (Dec. 31, 1963) unless it is authorized during the 1959 session of Congress.

AEC Still Optimistic

Nevertheless, the feeling in Washington is that the invitation for proposals, when it is issued next spring, will get a rousing response from Euratom utilities and their co-contractors, U. S. reactor manufacturers.

"Rather than a lack of projects," one AEC source said, "it appears likely to run over 1,000,000 kilowatts (the target), which may raise the question of expanding the program."

It is also considered likely that the inability of any U. S. manufacturer to handle more than one or two reactor projects simultaneously will "spread the work" and thus make the program more palatable to Congress. Another factor working against the grabbing of business by one or two companies is the element of financial risk in guaranteeing fuel and reactor performance.

Further, AEC officials point out, there is nothing to prevent projects outside the Euratom framework from going forward where the firms involved do not want to go through the rigamarole of government review.

In fact, this may be the no-choice course of the SENN and Edisonvolta projects in view of the "bail-out" charges made by Sen. Clinton P. Anderson (D-N. M.) before Congress adjourned. After raising the issue in the JCAE's hearings on Euratom, he made this statement on the floor of the Senate:

"At the hearing on Aug. 7 I asked Mr. Floberg whether the money could be used to bail out the deal in the case of the SENN project and Mr. Floberg answered that he had no objection whatsoever to our stating in our committee report that it is our specific understanding that no project on which bids have already been accepted, or no project on which contracts, either contingent or firm, have been entered into, shall be eligible for participation in this program.

"I also asked Mr. Floberg whether the money was to be used to bail out the Edisonvolta situation. Again Mr. Floberg answered my question in the negative. In other words, no money provided by the proposed legislation is to be used to bail out any existing proposal. . . . "

Armand Visit

Louis Armand, Euratom's president, arrives in Washington this month for courtesy calls on Secretary of State Dulles and President Eisenhower. He is also expected to sign the U. S.-Euratom agreement for cooperation at a State Dept. ceremony on Oct. 15.

Meanwhile, Back at Brussels . . .

In the meantime, a U. S. negotiating team (Commissioner Floberg, AEC's Nelson Sievering, Frank Vander Weyden and Myron Kratzer) arrived in Brussels last month to get on with the job of organizing an administrative force and laying out the program's ground rules ("There are a hell of a lot of administrative details to be worked out . . . and it's going to take a while to get programmed," a U. S. spokesman declared).

Among other things, full-time staffs must be exchanged and their offices established, and several joint boards must be selected—possibly one each for the designation of program criteria, review of proposals, administration of the research and development program on fuel, etc. The 5-year research and development program will proceed without awaiting review of the bilateral. It will be devoted to general fuel-cycle work on the light-water and organic-moderated concepts until specific reactors have been designated for construction; then, it will be swung into direct support of fuel improvement for these projects.

Fuel Guarantees

Before it authorized AEC to proceed with the program in August (NU, Sept. '58, 152), JCAE attached quite a few strings—most of them to the "keystone" of the arrangement: the fuel-element guaranty program. The fuel guarantees have two crucial functions: (1) to assure Euratom utility people that their fuel costs will have a ceiling; and (2) to create an atmosphere in which U. S. firms will find it easier to compete with British firms for Euratom business.

The guaranty program is complicated; it was complicated when submitted to Congress and is more complicated after Congressional modification. However, these facts stand out:

- For the first ten years of the program, AEC will guarantee fuel elements for a lifetime of 10,000 Mwd/ton at a maximum cost of $100/kg for stainless-steel elements and $140/kg for zirconium-clad elements. On the lifetime guaranty, AEC will give a processing allowance for any element failing to meet the warranty. On price, AEC will make up the difference when fabricators' quotations run over the $100 and $140 ceilings.
- JCAE has given AEC a mandate to "encourage a strong and competitive atomic-equipment manufacturing industry" in accepting proposals for guaranty coverage.
- AEC will draw up minimum burnup and cost standards that fuel suppliers will have to meet in bidding for Euratom business. The criteria, designed to limit AEC's guaranty expenses to $90-million, are to be published this fall.
- The manufacturer's guaranty must be as favorable as any other he offered for a comparable fuel element within "a reasonable period" before submitting his Euratom proposal; JCAE said this should be interpreted as meaning two months or so.
- AEC will obtain a royalty-free, nonexclusive, irrevocable license—for government use—of any patent on inventions or discoveries made by a fuel fabricator while manufacturing AEC-guaranteed elements.
- Every project eventually approved for construction under Euratom will be submitted for Congressional authorization, even though it meets the AEC warranties on burnup and price.

Cost to AEC

The guaranty program will cost the Commission nothing if every U. S. supplier, in contracting for a Euratom project, guarantees his elements for 10,000 Mwd/ton at prices equal to or lower than the AEC ceilings. However, in estimating its possible costs of $90-million over the ten-year period, AEC has assumed that burnup will average between 7,000 and 8,000 Mwd/ton and prices will range $120–$140/kg for stainless steel and $150–$175 for zirconium elements.

At this point, the burnup estimates are admittedly more concrete than the cost estimates. Nine fuel fabricators, meeting a JCAE request for information on a "company-confidential" basis in August, gave the Committee the impression that AEC's price guarantees will be considerably more costly than the burnup warranties. In other words, they indicated it would be easier to meet the burnup "goal" than the price "goals."

AEC assured the Committee that life warranties of $10,000 Mwd/ton and more had already been offered by U. S. fabricators (SENN and other projects) and that "two of the larger fuel-element manufacturers" were prepared to quote stainless steel elements at $115–$140/kg.

Frank K. Pittman, acting director of AEC's Reactor Development Division and director of the Office of Industrial Development, told JCAE:

"I think, taking the elements where we have given a guaranty—oxide elements clad in stainless steel or in zirconium—that the experience we have had to date in test loops in various and sundry tests around the country have clearly shown the expected life expectancy of these elements is well beyond 10,000 Mwd/ton and may be on the order of 15,000–20,000 Mwd/ton. . . . "

Pittman's testimony was seconded by Argonne National Laboratory in its evaluation of the SENN project bids by U. S. manufacturers (excerpts of the evaluation were furnished to JCAE by AEC).

"Uranium oxide fuels, already developed and having a satisfactory operating history," Argonne said, "show freedom from excessive irradiation damage at burnup to 25,000 Mwd/ton. Furthermore, the limitation may be appreciably above this level, with added possibilities of enriching to obtain higher burnup and of fuel management to achieve maximum uniform burnup."

It remains to be seen whether U. S. fabricators will get AEC off the hook on its commitment to hold guaranty support spending to $90-million. But AEC feels it has at least three built-in safeguards: 1. an "extremely pessimistic" approach to fuel-element capability; 2. Its assumption of no improvement in fuel technology over the ten-year period; and 3. the provision that it will get back half of any money it spends early in the program, when and if fuel lifetime goes over the 10,000-Mwd/ton guaranty.

GE/Ebasco Boiling Reactor Wins SENN Bidding for U. S.; Expected to Produce 13–14 Mill Power

The international race to sell a power reactor to Italy's Societa Elettronucleare Nazionale (SENN) was won last month by the International General Electric Co. and Ebasco Services, Inc., of the U. S., which were selected to build a 150-Mw(e) station for operation by end-1962 at the mouth of the Garigliano River in southern Italy.

The race drew world-wide attention as a competition between the U. S. and British reactor manufacturers for prestige position in the world reactor market (though France had one of the nine reactor entries in the bidding). Until the SENN decision was announced on Sept. 25, the U. K. had a commanding lead, with an Italian reactor contract already wrapped up (see page 23) and a second Japanese contract which is seemingly assured.

However, award of the SENN contract to a U. S. firm has lifted the enriched-uranium reactors of the U. S. program to a level of at least equal prominence with Britain's natural-U, gas-cooled designs and the outcome may have put enriched reactors in the lead. A significant factor in the SENN decision—reached with the help of an international panel of reactor experts—was the promise of IGE's duel-cycle, boiling-water design to permit substantial cuts in fuel costs over its lifetime. The best British bid, submitted by General Electric of England, was handicapped by its inability to match this promise of lower fuel costs. The British design also entailed higher capital costs than IGE's.

Other unsuccessful bidders were: **U. S.**—Westinghouse/Kaiser Engineers and H. K. Ferguson/Babcock & Wilcox, pressurized-water reactors; American Machine & Foundry/Mitchell Engineers/General Nuclear Engineering, boiling water; and Atomics International/Bechtel/Montecatini, organic-moderated: **Britain**—AEI/John Thompson and English Electric/Babcock & Wilcox, Ltd./Taylor Woodrow,

gas-cooled; and France—Societé Generale Alsthom, gas-cooled.

Winning Bid

The SENN reactor will be fueled with U oxide elements enriched to 1.5% in U^{235}. IGE will guarantee fuel burnup at 10,000 Mwd/ton, although calculated lifetime is 13,400 Mwd/ton and hoped-for burnup is 18,000 Mwd/ton. IGE will take complete responsibility for construction, supervision of design and purchase of all equipment; 70% of project components will be manufactured in Italy. Construction consultant on the project is Internuclear Co. of the U. S.

Initially, the station will produce electricity at 13–14 mill/kwh at 70% plant factor and 14% capital charges —against 11 mills for oil-fired stations—but costs are expected to come down with subsequent cores. Total cost of the station will be $58-million, not including fuel. A construction loan from the World Bank is assured but the amount and interest rate have not been settled.

Official target for operation of the plant is anytime before the end of 1962; unofficial target date, however, is Dec. 2, 1962, 20th anniversary of the day Enrico Fermi and his associates watched their makeshift reactor produce the world's first chain reaction at the Univ. of Chicago.

Fuel Supply

Italian reactor officials, in interviews with NUCLEONICS before and after the SENN announcements, indicated that U. S. policy on nuclear fuel has been unclear since the Euratom program was formulated. SENN has taken the position that Italy's power bilateral with the U. S., under which enriched U would normally be supplied to SENN, will be superseded by the U. S.-Euratom bilateral.

On this assumption, SENN has already applied to Euratom for allocation of its fuel; the allocation will be made by the Euratom supply committee which is to be established later this year (*see p. 30*).

AEC officials point out that the Italian bilateral has not been nullified, although it is assumed that Euratom will handle fuel allocation for any reactors built within the six member nations. However, it was also pointed out, there is no bilateral agreement with Euratom as yet and the Italian bilateral must remain effective at least until a Euratom agreement is ratified.

Disillusionment Clouds IAEA Meeting in Vienna

The International Atomic Energy Agency, now completing its first year of operation, is sagging badly from several serious ailments: a shortage of funds, international bureaucracy, a lack of interest among member countries and ill feeling between IAEA and the United Nations. In short, the Agency has failed to get off the ground during its first year and starts its second under clouds of disenchantment and international politicking.

This was the view of scores of delegates, including Pavel Winkler, outgoing chairman of the board of governors, as the agency membership sat down in Vienna last month to debate the agency's problems and work out a 1958–59 program. Among the problems are:

- The 23-member board of governors, which sets policy for the agency and directs its operations, has come under fire as an unwieldy managerial body which tends to settle controversies at the lowest common denominator.
- The board is divided by basic differences over agency functions: Should it operate its own facilities—such as the research reactor offered by the U. S.—or utilize member-owned facilities exclusively? Should its programs reflect the high level of technological efficiency among advanced member nations or should they attempt to meet the needs of those less advanced? What should the agency attitude be toward regional groups like Euratom, which, to some extent, are "little international atomic energy agencies"?
- Sterling Cole, IAEA director general, is only now beginning to feel at home in the difficult environment of international diplomacy and managerial complexity laced with personal and power politics. He has been criticized in some quarters as not up to the job since he operates under a handicap—insufficient administrative and technical experience.
- Finally, the agency's autonomy has piqued Dag Hammarskjold, UN secretary general, who feels it should be tied considerably closer to the UN in a subordinated role confined completely to the technical aspects of atomic energy. The Hammarskjold view is shared widely within IAEA by Winkler, India's Homi Bhabha and others, on the ground that the agency is being hobbled by international politics.

Fuel Supply

A major disappointment in the eyes of many delegates to the Vienna meeting has been the agency's inability to "take charge" of the international movement of fissionable material. Control of the world's nuclear fuel supply was felt to be a basic reason for the agency's creation. Moreover, such control was expected to be a significant source of agency revenues.

There is evidence that IAEA is swinging toward a more realistic position on fuel supply and might be willing to settle for jurisdiction over international fuel accounting. Until its fuel role is definitely settled at some future date, the agency appears likely to confine itself to the less politically potent areas such as dissemination of technology, training, safety and health problems, and the creation of international nuclear codes.

Certainly, as Winkler put it in an interview with NUCLEONICS, agency operations to date "have not fulfilled expectations."

A Shot in the Arm

The U. S. made a bold effort to bolster the agency's stock during the first week of the conference when John A. McCone, AEC chairman and chief U. S. delegate, announced that the U. S. was ready to underwrite a worldwide research program of peaceful uses of atomic energy through IAEA.

"My government," he declared, "will bear all the contract costs involved and, may I emphasize, the results of the projects undertaken would be made available through the agency to all member states."

As envisioned by McCone, the U. S. would assign research projects to the agency on high-temperature metallurgy, radioisotope technology and other broad areas of the field; IAEA, in turn, would assign the projects to research teams throughout the world.

"My government believes that there exists throughout the world today a wealth of scientific and technical competence which is not being brought fully to bear on the development of the peaceful uses of atomic energy," McCone commented. "We believe that the agency can draw upon this unused talent to the benefit of all."

The new AEC chairman also called for an intensive effort by the agency in the field of radiation.

TVA May Enter Bidding to Build Gas Reactor

AEC issued its invitation for industry proposals to build an advanced, gas-cooled reactor last month amid widespread speculation that a surprising bidder may be the Tennessee Valley Authority—giant of the public power industry.

Industry sources in Washington reported that TVA was "feverishly" preparing a proposal in response to AEC's Sept. 22 invitation. Moreover this was confirmed at the TVA staff level. However, the same TVA sources said that the staff's efforts have not been approved by the board of directors, who could kill the whole project. TVA had acknowledged in August that it was closely studying the CGR-2 designed by Oak Ridge National Laboratory and a pebble-bed design of Sanderson & Porter (NU, Sept. '58, 153).

In further acknowledging that a bid to AEC was under consideration, TVA sources said they were sufficiently advanced in their design work to meet the Nov. 22 deadline —if the TVA board gives its okay.

The Commission's Invitation

The AEC invitation was broad in some respects, narrow in others. Bidders are free to come in with their own designs (ACF and Kaiser are now completing a specific design for AEC) but the reactor must be gas-cooled and graphite-moderated with exit gas temperature of at least 1,000° F. Reactor size was unspecified ("sufficiently large to serve as a prototype for a full-scale plant of similar design") but construction must be completed by Dec. 31, 1962.

Under the grace-period procedure agreed to by the Joint Committee on Atomic Energy, AEC was given 30 days to invite industry proposals (after Aug. 28), another 60 days to receive replies, and another 90 days to negotiate any promising proposals received. If no industry or AEC-industry cooperative project can be agreed upon during this 90-day period, AEC must contract the job out as a federal project ($20-million has been appropriated for construction beginning next spring).

If a cooperative project is worked out—one which would include AEC help via fuel charge waiver, use of AEC facilities, or research and development aid—the arrangement would have to be presented to JCAE for authorization during the 1959 session of Congress.

Piqua Reactor Jeopardized by Adverse Site Report

"The tentative view of the Advisory Committee on Reactor Safeguards is that the site is not a suitable one."

This tersely-worded but preliminary finding of ACRS, made public last month by Sen. John W. Bricker (R-Ohio), has left the Piqua, Ohio, reactor project near collapse. AEC officials said the disclosure made it doubtful that the organic-moderated reactor project would proceed to construction, since it has raised serious doubts among the Piqua citizenry about the safety of the 12.5-Mw(e) station and has given heavy publicity to the fact that Piqua would be the first commercial reactor built without a containment sphere.

Bricker, a member of the Joint Committee on Atomic Energy and champion of private power, announced the tentative finding of ACRS a few days after it was passed along to JCAE by Acting AEC Chairman Vance in a letter dated Sept. 5. Said Bricker:

"I am naturally disappointed that residents of the Piqua area may be denied an opportunity to contribute toward the work of harnessing the atom for peaceful purposes. Nevertheless, I am sure that all Ohioans join with me in the belief that atomic power, important as it is, must always be secondary to considerations of public safety.

Despite the public opinion problem, however, all three interested parties—AEC, the builder; City of Piqua, the operator; and Atomics International, the contractor—said they would not drop the project until a final safety evaluation has been completed; the hazards summary report of AEC, including final advice from ACRS, is scheduled to be ready later this month, will be submitted immediately to JCAE.

AEC, which almost a year ago took over the project under JCAE mandate (NU, Sept. '57, 21), accepted a major share of the blame for permitting the project to go so far before disposing of such a basic issue as site evaluation. Assignment of the blame, however, appeared to be academic in view of an AEC official's comment that the site was "the only spot in the Piqua area where the reactor could go."

The project was proposed by the City of Piqua in January of 1956 (NU, March '56, 19). It was one of seven public power projects proposed under the second-round demonstration program. Four of these have since been dropped; only Piqua, Elk River (NU, June '58, 25) and Chugach (NU, Sept. '58, 156) survive.

None Oppose License For GE Test Reactor

AEC's new office of hearing examiners conducted its first proceeding last month: a public hearing on the issuance of an operating license for the General Electric Testing Reactor at Vallecitos.

The hearing, conducted in AEC's high-ceilinged auditorium at Germantown, Md., by Examiner Samuel W. Jensch, lasted only 42 minutes. There was no opposition to issuance of the license, and the examiner was expected to render his decision—subject to Commission review—with little delay.

The reactor, for which a construction permit was issued March 11, is a pressurized-water facility with a maximum power of 30 Mw(th). GE expects the reactor to be a major tool for fuel-element development and environmental tests.

The AEC staff supported GE in recommending issuance of an operating license. Clifford K. Beck, chief of the hazards evaluation branch, testified that the maximum credible accident to the facility would not result in unacceptable exposures to the public. AEC's advisory committee on reactor safeguards also has given the reactor its blessing.

The AEC staff has approved GE plans to conduct a pressurized-water experiment in one loop and a boiling-water experiment in another, beginning this fall. But additional AEC approval would have to be obtained before all seven loops were put into use.

GE estimates that the maximum credible accident would release 730,000 Btu of energy—and this would require three coincident failures before it could occur.

Beck pointed out that GE would be directed to conduct no experiments which, in case of accident, could introduce more than 1.4% reactivity.

OEEC Insurance Group Proposes Liability Solution

A committee of European insurance experts is expected to take a giant step this month toward solution of the third-party liability problem of power-reactor operation on the Continent—a solution which has become particularly urgent since the advent of the U. S.-Euratom program.

The committee will recommend to the 18 member nations of the Organization for European Economic Cooperation that they ratify a proposed convention exempting manufacturers and other nuclear equipment suppliers from all liability arising from reactor operation. The liability would fall completely on the reactor operator; however, it would be limited to an amount for which the operator could get coverage on the commercial insurance market.

Ratification of the convention by the OEEC nations—including all six Euratom governments—is anticipated as a matter of course by early next year.

Several U. S. equipment suppliers have told NUCLEONICS that no reactor for which they contributed components could be operated until such action as this was taken. Their contracts with European utilities, they declared, will include clauses holding them harmless or preventing reactor operation until an acceptable solution like that proposed for OEEC action has been worked out.

Moreover, solution of the problem on this Europe-wide basis is deemed essential because of the possibility that a major incident would cause damage in a neighboring country where the supplier was not exempt from all liability. Eventually, the problem will go to the International Atomic Energy Agency for consideration of a world-wide convention.

AEC Releases U Statistics on First Half '58 Output

AEC has released monthly and total statistics on domestic uranium production for the first half 1958. On June 30, reserves were an estimated 78,500,000 tons and ore stockpile stood at 1,956,531 tons. Ore receipts at private and AEC stations January–June were 2,440,000 tons; ore fed to process totaled 2,471,000 tons. Average price paid by AEC for U concentrates was $9.34/lb.

A Tribute to Gordon Dean

The numbing shock and grief occasioned by Gordon Dean's death make it most difficult to try to view his accomplishments in perspective. I am sure that time will show his leadership in atomic energy had long-lasting importance.

I thought that he represented an ideal leader for meeting the requirements of today's great organizations, whether private or public. Gordon, the lawyer, and in many ways, the scholar, seemed quite different from the conventional concept of the typical line executive. But no one who watched him in action, either in his three years as chairman of the Atomic Energy Commission, or afterwards in business, doubted the quality of his leadership and his unique understanding of the path of progress. The root of his success was, naturally, his own personality and his tremendous and versatile capacities; but of great importance was his understanding of the functioning of large organizations and his concept of their role in our society.

Of his personal attributes I think the most remarkable were his great intellectual curiosity and his versatility in absorbing knowledge. He sought to learn all he could about science and scientific development, spurred on by his conviction that they represent the most important and fascinating influence in our world. He devoted his fine mind to acquiring the essence of many fields of science; he possessed a keen intuitive ability to appraise scientists and to understand the workings of the technical mind. Instead of resisting change, he welcomed new horizons and the anticipation of the future and derived great satisfaction from making effective the ideas of creatively gifted individuals whose dreams seemed to him to ring true.

Besides broad curiosity and vision, he possessed the vigor and ability to get important things done through organization. He was a superb tactician. In the AEC, as a particular example, I have always considered his handling of his first few months of the chairmanship as a classic of administration. He was only 44, a new commissioner, and a question mark to the staff, most of the Joint Committee on Atomic Energy, and the public. In an incredibly short time, he had established himself, had healed most of the wounds in a Commission under heavy fire, and had made such a solid impression upon Congress and the public that the AEC achieved unquestioned and invaluable support within a matter of months.

This excellent beginning was followed by a period of great accomplishment. Gordon was able to handle—and with seeming ease—a variety of demanding situations; he thoroughly understood the importance of the momentum of large organizations, and spent a great part of his effort in making sure that the general manager and staff had the backing they needed to carry the tremendous burden that the Korean War experience had forced upon them. All of this required diplomacy and tactical skill of the highest order, sometimes in dealing with his fellow commissioners, but more often with other agencies of the government, the Congress and the press. As one example, none of us who was there will forget his courage and leadership in the appropriations battle in the Congressional session in the summer of 1952; and it was characteristic of Gordon that he retained the friendship of those who were sometimes his most determined adversaries. It was his tenet that controversy should not lead to personal animosity.

In his personal relationships, he had a unique ability to be a warm and kind friend and yet objective in appraising his friends and their problems. It was this paradoxical combination which made him sought by innumerable people for his counsel; they knew that they were talking to a friend who would be both human and wise.

Gordon Dean filled a great role: a devoted, deeply perceptive and articulate advocate who knew the importance of erecting a firm bridge of understanding concerning the implications of breathtaking compression of scientific progress upon our hopes for a better world. The world has lost an able citizen; those of us who knew him have lost a beloved friend.

This memorial to the late Gordon Dean was written by Eugene Zuckert, a close friend and co-member of the Atomic Energy Commission. Dean was killed in an airplane crash at Nantucket, Mass., August 15.

Reactor News

OMRE TAKES AL-CLAD FUEL LOADING
Aluminum-clad fuel elements, of the type which would fuel a large-scale organic-moderated power reactor, were installed in the Organic-Moderated Reactor Experiment (OMRE) at the National Reactor Testing Station more than a month ago. The loading is part of a program to determine eligibility of the elements for AEC guarantees under the Euratom agreement; the OMR concept itself has already been accepted as "proven."

TRIGA REACTOR SOLD TO ITALY'S CNRN
A contract for Rome's first nuclear reactor was signed at the Geneva Conference by General Atomic and the Italian National Committee for Nuclear Research (CNRN). An above-ground version of GA's TRIGA (Mark II), the reactor will be installed at CNRN's new research center by early in 1959; operating power level will be 30 kw with intermittent runs up to 100 kw.

MALLORY-SHARON CUTS PRICES OF ZR
Substantial reductions in the price of reactor-grade zirconium sponge and chunklets were announced last month by Mallory-Sharon Metals Corp., Niles, Ohio. The company said the reductions flowed from process improvements, rather than competition. M-S says it is using a sodium reduction process, instead of the more widespread magnesium process, while maintaining AEC standards. The new prices are $6/lb for sponge and $6.25/lb for chunklets in lots of 500 lbs or more and $6.50 and $6.75, respectively, in 100–500 lbs; in the same order, previous prices were $7, $7.50, $8, $8.25.

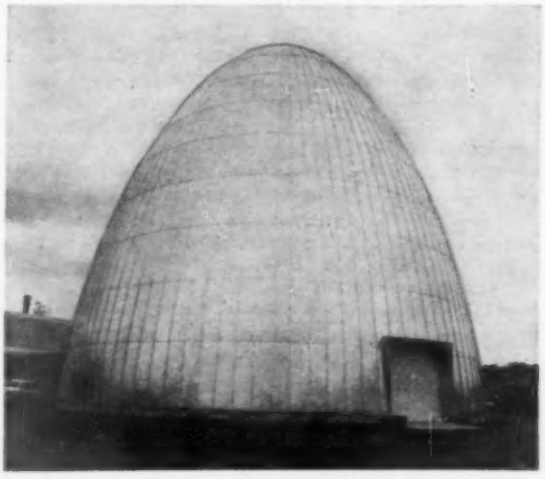
MARTIN BEGINS ZERO-POWER TESTS FOR ARMY
The Martin Co. has initiated a series of zero-power reactor experiments for the Army's advanced packaged reactor program. The test assembly is water-moderated and fueled with highly enriched U foil encased in stainless-steel flat plates; core content, volume fractions and core size can be varied over a wide range. Several experiments are planned in power flattening, nucleate boiling, reactor control and higher core loadings.

SWORDFISH GOES INTO SERVICE
The second of four nuclear submarines of the *Skate* class, *Swordfish*, was commissioned at Portsmouth Naval Base, N. H., on Sept. 15. *Seadragon*, launched at Portsmouth at Aug. 16, is being completed and the fourth, *Sargo*, was commissioned on Oct. 1 at Mare Island Naval Shipyard in California.

FUSION TO BE DECLASSIFIED BY OCT. 31
AEC declassification officials said last month that all controlled-fusion information—except that specifically discussing military applications—will be declassified by the end of this month. A declassified version will be issued of any report found to contain such military allusions. Meanwhile, word has gone out to everybody in the fusion program confirming AEC's new policy that everything in the program from here on out is "born unclassified."

B & W TO BUILD TEST FACILITY FOR LMFRE
Babcock & Wilcox will build a critical facility for the Liquid Metal Fuel Reactor Experiment (LMFRE) at its critical experiment laboratory in Lynchburg, Va. To be located alongside the critical experiment being constructed for the merchant ship reactor, the facility will provide design information for LMFRE; both experiments will be controlled from the same console. Tests will include determinations of critical size for various fuel and reflector configurations, as well as U^{235}-to-bismuth ratios; determinations of control-rod worths; and the effects of fuel in the reflector regions and plenums of the LMFRE.

AEC LICENSES IRL REACTOR NEAR PRINCETON
The research reactor American Machine & Foundry built for Industrial Reactor Laboratories, Plainsboro, N. J.,



(above) was being readied for operation last month by IRL. Plainsboro is 4 mi northeast of Princeton. The 5-Mw(th), pool-type reactor will be operated by AMF Atomics for the IRL group (AMF, American Tobacco, Atlas Powder, Continental Can, Corning Glass, National Distillers, National Lead, RCA, Socony Mobil and U. S. Rubber). The reactor is expected to go critical some time this month.

NEW RESEARCH REACTOR OFFERED BY VITRO
Vitro Corp. of America has completed design of a small, tank-type research reactor controlled entirely by its negative temperature coefficient. VITCOR (Vitro temperature-controlled reactor) is available for manufacture under Vitro licensing but will not be manufactured by Vitro. Rated at 1 kw, the unit is designed to go critical at 65° F; with a failure of any kind, it will absorb its own heat, or that of the surrounding air, and go subcritical. For startup a small refrigerator cools the reactor below 65°, which puts it on a positive period and brings it up to operating power; the power level is then set by the refrigerant water temperature and flow rate, and no other controls are necessary. Core is a right cylinder 16 in. dia × 16 in. high consisting of 36 radial fuel plates. Reactor vessel is contained in a combination lead, graphite and high-density-concrete shield 13 ft in dia and 8 ft high.

REACTOR NOTES: AI, ELK RIVER, PRTR
Atomics International has been asked by Spain's Junta de Energia Nuclear to design a **three-way reactor**—a producer of both electricity and radioisotopes and a test facility for fuel elements. The reactor would be heavy water moderated, organic-cooled, and capable of tie-in to a 20 Mw(e) generator . . . A $500,000 contract for the **Elk River** containment shell has been awarded to Chicago Bridge and Iron; ACF Nuclear is prime contractor . . . AEC will open bids on Phase III construction of the **plutonium recycle reactor**—including reactor vessel—on Oct. 29 at Richland, Wash.

ROUNDUP

World News

Swiss Westinghouse Established in Geneva

The Westinghouse International Atomic Power Co., a subsidiary of Westinghouse International, has been established in Geneva to serve the nuclear power needs of Euratom and other European countries. Board chairman of the Swiss firm is Kenneth D. Nichols, former AEC general manager. Other officers: Raymond Giguet, former director general of Electricite de France, president; and Peter G. Schmitt, former Westinghouse International executive, vice president and general manager. Westinghouse has manufacturing and technical assistance agreements with Fiat in Italy, Siemens in West Germany and Ateliers de Constructions Electriques de Charleroi in Belgium; a similar agreement is under negotiation with French interests. Westinghouse said this network of agreements would permit extensive manufacture of Euratom reactor components in Europe.

Cancelled Plant Indicates Swedish Shift

Sweden has cancelled the 75-Mw(th) space-heating reactor known as "Adam" projected for construction at Vasteras. Reports from Stockholm indicate a swing away from heat reactors in favor of those producing both electricity and heat or electricity only; work is going ahead on a combination station at Agesta, a Stockholm suburb, which is designed for 70 Mw(th) and 15 Mw(e) but which may be redesigned for electricity only.

U. K., West Germany Near Agreement on Bilateral

The United Kingdom and West Germany neared agreement last month on a bilateral agreement clearing the way for German purchase of British reactors. The pact, worded to take account of West Germany's Euratom obligations, is expected to be laid before the British and German cabinets in November for probable ratification before Christmas. Best prospects for Calder-Hall type plants are RWE (NU, July '58, 26) and a utilities combine in Southern Germany, which, however, is having financial troubles.

Italians Launch Nuclear Navy, Atomic Forum

Italy's naval weapons chief, Gen. A. Matteini, said a start will be made by mid-November on construction of Italy's first nuclear submarine, the *Giulio Verne*. She will be smaller than the *Nautilus* but faster and more maneuverable and outfitted primarily for transport duty. Launching is scheduled before end-1959 . . . An Italian version of the Atomic Industrial Forum has been formed in Milan.

Euratom Nuclear Supply Agency Created

The Euratom Cabinet Council has approved the statute creating a Nuclear Supply Agency for the six member countries. The agency, capitalized at $2.4-million, will assign all uranium and other fissionable materials consumed by the Euratom countries.

Huge Indian Station Authorized; January Start Seen

India's Atomic Energy Commission has been authorized to proceed with construction in January of a 250-Mw(e) power station, the country's first, for completion in 1964. British equipment for the facility, a Calder-Hall type, will be supplied on a deferred payment basis. The project will be executed in three stages to generate 1,000 Mw(e) by 1967; location is Ahmedabad, Bombay state, a major industrial city.

U. S. Official Urges World Convention on Atom Shipping

Richard P. Godwin, director of nuclear merchant ship work at AEC and the Maritime Administration, has called for an early start on development of an international convention "specifically recognizing the unique features of nuclear ships" and embodying a new concept of liability and liability limitation. Godwin addressed the International Union of Marine Underwriters meeting at Salzburg, Austria.

Australian Reactor Dropped, Another Recommended

The American-controlled Mt. Isa Mines, Ltd., Queensland, Australia, has postponed indefinitely its plan to install a power reactor; a coal-burning station under construction will meet immediate expansion plans . . . On the other hand, Australia's Atomic Energy Committee has recommended the building of a $60-million nuclear power station in South Australia; the recommendation is under study.

Norway Plans Small Reactor for Boiling Water Study

The Norwegian Institute for Atomic Energy (IFA) is planning construction of a pool-type, zero-energy reactor at the combined Norwegian-Dutch Atomic Energy Research Institute (JENER) in Kjeller. The unit's primary function will be to further development of boiling water reactors for both stationary and marine use. It will be built by IFA and an industrial group, NORATOM; five tons of heavy water (if needed) and some components will be ordered from the U. S. The reactor will use natural U and either heavy or light water as moderator-coolant.

British Firm Schedules Beryllium Plant

What is described as Europe's first plant for production of semifabricated beryllium will be completed by Imperial Chemical Industries, Ltd., late next year; it will produce rods, tubes, plates and finished machined parts. Initial output will go to the U. K. Atomic Energy Authority for cladding of fuel elements developed for the high-temperature Advanced Gas-cooled Reactor (AGR), where fuel surface temperatures are expected to reach 600° C.

Spain Explores Euratom Role

Spain is showing signs of a desire to join France, Germany, Italy and the Benelux countries in their Euratom and Common Market ventures. The Marquis of Loriana, member of the Committee of Power Development, recently announced formation of a government commission to study the feasibility of Spanish membership in these organizations . . . Spain has already decided to join the International Bank and Monetary Fund this fall, according to reports from Madrid, to make itself eligible for a long-term loan. The money will go into major power projects, including nuclear reactors, and into heavy industry.

German Firm Reports Orders for U Plants

Five orders from three countries for U processing plants have been reported by DeGUSSA, Frankfurt, Germany: from India, orders for a reactor-grade U-metal pilot production plant and several facilities for the production of fuel elements (from U smelting plant to measuring and testing apparatuses); Italy, orders from two groups for high-vacuum smelting plants (one delivered, the other close to operation); and Sweden, a special furnace for sintering high-density U-oxide cylinders. Degussa also announced a licensing agreement with Sweden's Aktiebolaget Atomenergie.

News in Brief

AEC Reorganization Stresses Labor Relations
AEC has split its personnel staff into two groups: the Office of Industrial Relations, concerned with the manpower and labor problems of the Commission's contractors; and the Office of Personnel, concerned with the Commission's own manpower problems. Oscar S. Smith, director of the now defunct Division of Organization & Personnel, has taken over the industrial relations office. Arthur L. Tackman, former assistant director for management appraisals, Division of Inspection, will direct the Office of Personnel. AEC officials said the reorganization represented no change in policy but reflected "a feeling that AEC must emphasize the industrial relations area" and "must concern itself [more] with the industrial relations of its contractors."

Olin Mathieson, American Lava Open Fuel Plants
Private capacity for production of nuclear fuel elements jumped significantly in late August with the opening of new facilities by both Olin Mathieson Chemical Corp. and American Lava Corp. at Montville, Conn., and Chattanooga, Tenn., respectively. Montville's output will go almost entirely to military reactors until the commercial market develops further. Chattanooga was designed for the manufacture of ceramic urania or urania-thoria pellets from ⅛ to 1 in dia; cylinders, tubes, plates and other shapes can also be fabricated at the plant. Until Montville went on the line, Olin Mathieson had been confined to pilot-plant operation in New Haven, Conn.

Texas Co. Completes Radiation Research Lab
With the delivery of 29,100 curies of cobalt-60 by Atomic Energy of Canada, Ltd., the Texas Co. has completed what it claims to be "the world's most fully-equipped industrial radiation research laboratory," Beacon, N. Y. The lab also includes a 6–10-Mev linear electron accelerator and a 3-Mev positive-ion Van de Graaff generator.

NDA Moving into New Quarters, Expanding Others
Celebrating its tenth anniversary, the Nuclear Development Corp. of America began moving last month into a new research and development center (eventually to be company headquarters) at Eastview, Westchester County, N. Y. NDA has also been expanding its laboratories at Pawling, N. Y., adding an engineering services building, a low-power research reactor and reactor-engineering test facilities. The present headquarters building at White Plains will be devoted to engineering, experimental and fabrication activities after the move to Eastview later this year.

Westinghouse Discovers Promising Thermionic Materials
A series of mixed-valence ceramics promising heat-to-electricity conversion efficiencies of 20% has been discovered by Westinghouse. The materials have achieved efficiencies of 7%, according to research chief Clarence Zener, and offer the prospect of 20% within 2–3 years. The Navy has had a thermoelectric program underway for some time and hopes to have a pilot propulsion system operating in 12–18 months; Westinghouse is a prime contractor in this program.

Merger Planned by Five U Affiliates of Atlas Corp.
Five uranium affiliates of Atlas Corp. plan to form a publicly owned company in which Atlas will be the largest stockholder. The merger, subject to stockholder approval later this year, would produce the Hidden Splendor Mining Co. with assets of more than $50-million and U ore production of 500,000 tons per year; Hidden Splendor would also have an interest in the Uranium Reduction mill at Moab, Utah, and the Homestake-New Mexico Partners mill near Grants, N. M.

Waste Disposal Notes
The State of California settled its several-months' dispute with AEC-licensed waste disposal companies by working out a voluntary agreement on five disposal sites more than 100 miles off the California coast. The pact, which is only morally binding, was agreed to by Isotopes Specialties, Inc., Pacific Marine Service and Nuclear Engineering Co. Radioactive wastes will be sunk in water at least 2,000 fathoms deep. . . . Nuclear Engineering, whose bid for a more extensive AEC license had been delayed while the agreement was worked out, was cleared for disposal activities in both the Atlantic and Pacific a few days after the agreement was reached . . . Also cleared for at-sea disposal were: Walker Trucking Co., New Britain, Conn., and New England Tank Co., Cambridge, Mass. Walker's license covers disposal of both radioisotopes and source material (U and Th); New England's covers only radioisotopes.

AEC Proposes First of Permanent Indemnity Rules
Taking the first in a series of steps expected eventually to lead to a set of permanent reactor indemnity regulations, AEC has tentatively **1.** approved the insurance forms of two commercial pools; and **2.** established the standard form it will use to indemnify licensees up to the legal $500-million limit. Neither action is final until interested parties have had an opportunity to comment and the comments can be studied. The private pool policies tentatively approved were those of Nuclear Energy Liability Insurance Assn. and Mutual Atomic Energy Liability Underwriters. AEC has been operating under temporary indemnity rules since the program was established a year ago (NU, Oct. '57, 21).

MA Invites Ship Lines to Join Atom Training Program
All U. S.-flag steamship companies have been invited to sponsor trainees in the crew training program for the NS *Savannah*, but only employees of the ship's operator, States Marine Line, will get free tuition. Details of the program are still being worked out but it is roughly scheduled for 15 months at facilities of Babcock & Wilcox, New York Shipbuilding and AEC. The selection of States Marine as Savannah operator was challenged in the last days of the 85th Congress by Rep. Herbert Bonner (D.-N. C.), chairman of the House Merchant Marine Committee. He charged that a special advisory board on selection had unanimously recommended another operator; he then linked the ignoring of this advice to the friendship of a States Marine executive with AEC Chairman McCone.

Radiation Safety Developments
The International Association of Industrial Accident Boards, meeting at Seattle Sept. 9–11, asked AEC to issue radiation use licenses only to plants in states having adequate radiation safety and compensation standards. The group also urged that AEC's jurisdiction be broadened to include the issuance of safety codes and standards—covering transport, handling and use of radioisotopes—in areas where reactors are built. . . . New York City's Health Dept. served notice to doctors, dentists, business firms and institutions that they must register if they use X-ray machines, radioisotopes or other radiation sources. The notice is the first step in a city-wide program of radiation hazards control.

ROUNDUP

Japan Delays U. K. Contract

The ascendancy of a new atomic czar in Japan has brought postponement of the selection of a British power reactor and a reappraisal of the entire reactor program. The plan to purchase a Calder-Hall type as Japan's first reactor has not been abandoned, but the naming of a British supplier has been delayed until later this year, at the earliest, and possibly until the spring of 1959.

This second look at Japan's program is being made under the direction of Takeo Miki, who succeeded Matsutaro Shoriki as top man in the program earlier this year. Miki came on the scene after Shoriki had invited three British consortia to submit gas-cooled reactor bids by last July 31 (General Electric, English Electric and Associated Electric).

650-Mw Station for U. K.

Britain's Central Electricity Generating Board has announced plans to build a 650-Mw(e) nuclear power station—Britain's seventh and largest. CEGB has applied to the Ministry of Power and to local authorities for okay on a coastal site at Sizewell, NE of London.

Pu Dual Reactor Okayed

AEC has ordered General Electric to proceed with final design of a plutonium production reactor capable of later conversion to production of electricity, as well. The $145-million reactor was authorized by Congress in August but a go-ahead had been delayed pending completion of a Pentagon study on need for the reactor.

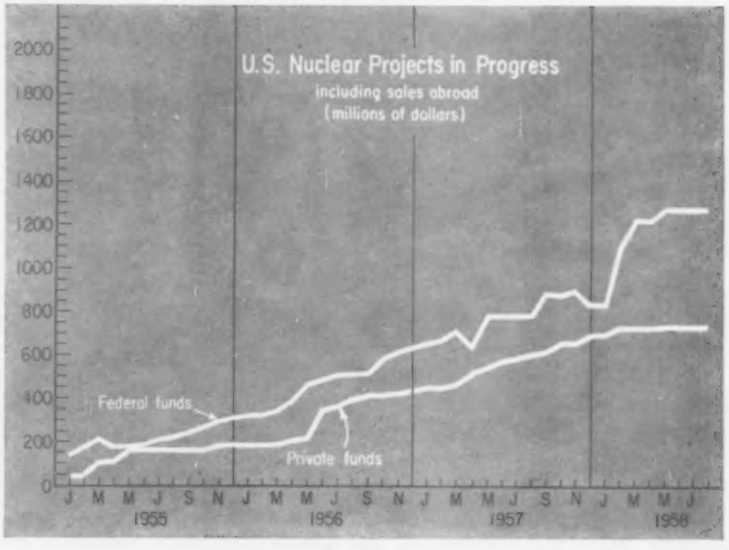
Only the $10-million design money has been released by the Budget Bureau but construction is considered certain, probably beginning early next year at Hanford on a schedule calling for completion in 1962. GE will handle design of reactor and some unspecified support facilities; AEC is negotiating with Burns & Roe for other design work.

McMillan Heads Livermore

Edwin M. McMillan has been selected to succeed the late Ernest O. Lawrence as director of the Univ. of California Radiation Laboratory, Berkeley. Lawrence died late in August after a major abdominal operation.

McMillan, one of the nation's most distinguished research physicists, is a member of the General Advisory Committee to AEC. He was appointed deputy director of lab by Lawrence several weeks before his death.

NUCLEONICS Statistics of the Month



	Latest month	Month ago	Year ago
Nuclear Contracts *—			
Contracts awarded for federal projects ($10³)	3,638	10,501	8,610
Proposed construction, privately-owned ($10³)	0	0	0
Contracts awarded, private work ($10³)	4,375	1,000	5,151
Backlog of private projects ($10⁶)	249	249	209
Access Permits †—			
Access permits issued	18	24	27
Total access permit holders	1,432	1,417	1,363
Isotope Use †—			
Applications for isotope use	548	512	345
Cumulative total of isotope users	4,089	3,790	4,182
ORNL shipments (curies)	17,618	58,119	9,667
Public and private export shipments	272	286	269
Employment †—			
AEC employment	7,005	6,815	6,898
Construction and design contractors' employment	9,895	10,328	12,727
Total operating contractors' employment	103,686	113,686	99,142
Production workers	51,144	51,400	50,928
Research and development employees	46,177	45,087	41,918
Miscellaneous workers	6,365	6,871	6,566

U. S.-built Reactors ‡—

	Operating	Building	Contracted
Power, domestic	1	6	8
Power, for export	0	1	2
Power experiments and pilot plants	7	4	1
Military and naval	5	23	12
Research and test, domestic	47	23	39
Research and test, for export	8	13	9
Foreign-built Reactors ‡—			
Power, domestic	6	24	11
Power, for export	0	0	3
Research and test, domestic	29	13	10
Research and test, for export	6	6	1

* From *Construction Daily*, a McGraw-Hill periodical † From AEC ‡ NUCLEONICS figures

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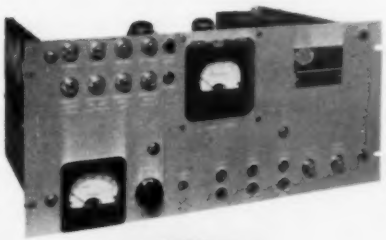
AMPLIFIERS

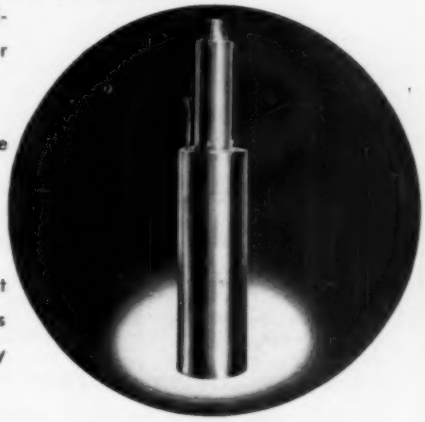


RCL's Composite Safety Amplifier combines the essential features of Period, Sigma and Magnet Amplifiers on one chassis to provide a compact safety control package which supplies current to magnet coils, initiates reactor shut down, etc.

RCL, in addition to the above, offers an extremely reliable line of reactor control instruments such as Log N, Linear, Period, Sigma, and Magnetic Amplifiers, Log Count Rate Meters, and Power Supplies. All chassis are suitable for standard 19" rack mounting or can be supplied with cabinets.

To complete your instrumentation requirements, RCL also features a complete group of monitoring instruments.

DETECTORS



The Hurst-type, polyethylene-lined Fast Neutron Detector illustrated at right operates on the proton recoil principle. The instrument detects neutrons with energy levels between 0.1 and 15 mev. RCL can fill almost every detector need in your reactor control system.

RCL detectors have many applications, including monitoring reactor facilities. For more information on RCL's monitoring and reactor control instruments, write RCL today.

SURVEY METERS

RCL's Fast-Slow Neutron Survey Meter is a completely portable, battery operated, transistorized instrument featuring printed circuitry, reduced power requirements and light weight. Fast and slow neutrons are measured independently by either a fast or slow counter tube as selected by the operator. Weight less than 10 pounds. Dimensions: 21½" x 6" x 6".

Individual fast or slow neutron survey meters are also available.

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See RCL's fifteen-minute educational film, "Spectrum Analysis by Multi-Channel Analyzers." To arrange for a private showing at your company write RCL today.

CAST nuclear stainless steel valves and fittings now proved economical with superior strength

Cooper Alloy cast nuclear-service stainless steel valves and fittings are saving money, providing greater strength in AEC-contract plants today. Here's the story:

This Cooper Alloy stainless steel fitting for nuclear service, here being machined, possesses a yield strength of 26,000 psi at 650°F.—20% higher than values specified by code.

Cooper Alloy 16" stainless steel gate valve body illustrates the wide range of nuclear valves and fittings now being cast by Cooper Alloy for atomic energy service.

YIELD STRENGTHS: CAST vs. FORGED STAINLESS STEEL

Cast Stainless Steel
SA351-CF8.....18,400 psi @ 650°F.(1)

Forged Stainless Steel
SA182-F8-304.....17,900 psi @ 650°F.(1)

Cooper Alloy Cast Stainless Steel
ASTM351-CF8.....22-27,000 psi @ 650°F.(2)

(1) Figures represent minimum yield strengths required by ASME Unfired Pressure Vessel Code, Section VIII, and have been calculated as follows:

$$YS = \frac{\text{allowable stress}}{62.5\%}$$

(2) Figures taken from tests of actual heats of material manufactured by Cooper Alloy for the AEC's SPERT III program at Idaho Falls, Idaho (see Nucleonics, Aug. '57).

Strength: As the figures in the accompanying chart show, Cooper Alloy is currently achieving what many have described as "the impossible": producing 304 ELC stainless cast valves and fittings consistently with yield strengths of 22-27,000 psi at 650°F.! These superior physical properties are finding wide application in meeting the exacting strength and economy demands of the nuclear industry.

How It's Done: These outstanding properties have been achieved by utilizing skills developed through Cooper Alloy's over 35 years of experience in casting stainless steel exclusively. In particular: • Use of proper directional solidification, achieved by proper mold design, plus foundry know-how in metal feeding, ensures a sound solid casting. • An exact balance of chemical composition develops the maximum strength characteristics inherent in the complex structure of stainless steel alloys. • Incorporation of foundry considerations into valve and fitting designs ensures maximization of the alloy's and the item's potential.

Quality Controls: In addition to all usual checks, such as 100% X-ray examination and dye-penetrant surface testing, all components are subjected to a 6,000 psi hydrostatic pressure test.

The Costs: Savings up to 40% have been achieved with sizes of fittings running from 8"—24".

Want more information? Telephone or write the Nuclear Division, Cooper Alloy Corporation, Hillside, N. J.

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THIRTY-FIVE YEARS OF STAINLESS STEEL PIONEERING

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A 475,000 KW power plant in Louisiana. America's Engineering Test Reactor in Idaho. A 100,000 KW industrial steam power plant in Pennsylvania. The engineering study for the AEC's Gas Cooled Graphite Moderated Power Reactor. A $10,000,000 dual-purpose process steam and power plant. New nuclear development projects in Europe, Asia and Latin America. This is Experience—electric power from both nuclear and fossil fuels. To which Kaiser Engineers couples ingenuity to pioneer, to develop new methods, to achieve better plants, quicker, for less. For experience, ingenuity, and a cost conscious approach, call or write KE. Today.

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U.S.S. Nautilus

General Dynamics' photos

Where there's atomic propulsion, there's a Crane Valve

U.S.S. Skate

U.S.S. Seawolf

Call the roll of the Navy's Nuclear Fleet!

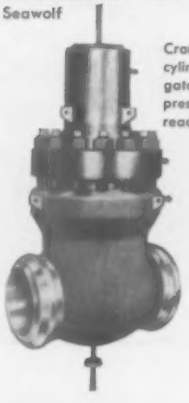
Nautilus . . . Seawolf . . . Skate . . . Sargo . . . Swordfish . . . Skipjack . . . Seadragon . . . Triton . . . and more to come!

U. S. S. Longbeach . . . Carrier CVAN-1 . . . Destroyer DDN-1 . . . and more to come!

On every one of these vessels, *Crane valves* provide positive fluid control in their respective reactor systems.

Crane, pioneer in basic research and production of valves for control of radioactive fluids, keeps pace with every new development, every new need, of atomic engineers for installations afloat and ashore.

This is an important fact to remember if you are planning atomic facilities of any kind. Even though your plans are still on the boards, NOW is the time to talk to Crane about valves.



Crane 16-inch, cylinder-operated gate valve for pressurized water reactor system.

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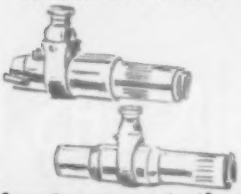

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advanced-design instrumentation, soundly made, and backstopped

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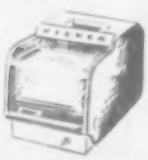
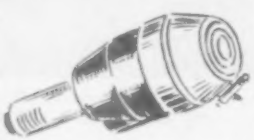
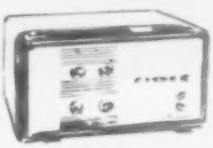


SURVEY METERS

FOCUSING COLLIMATORS



SPECTROMETERS



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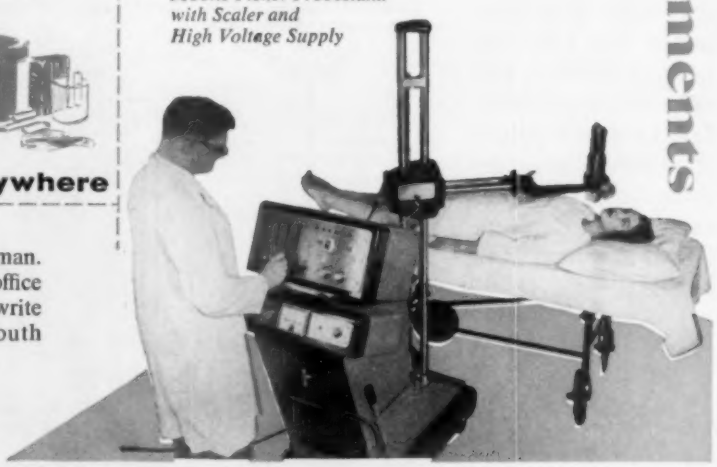
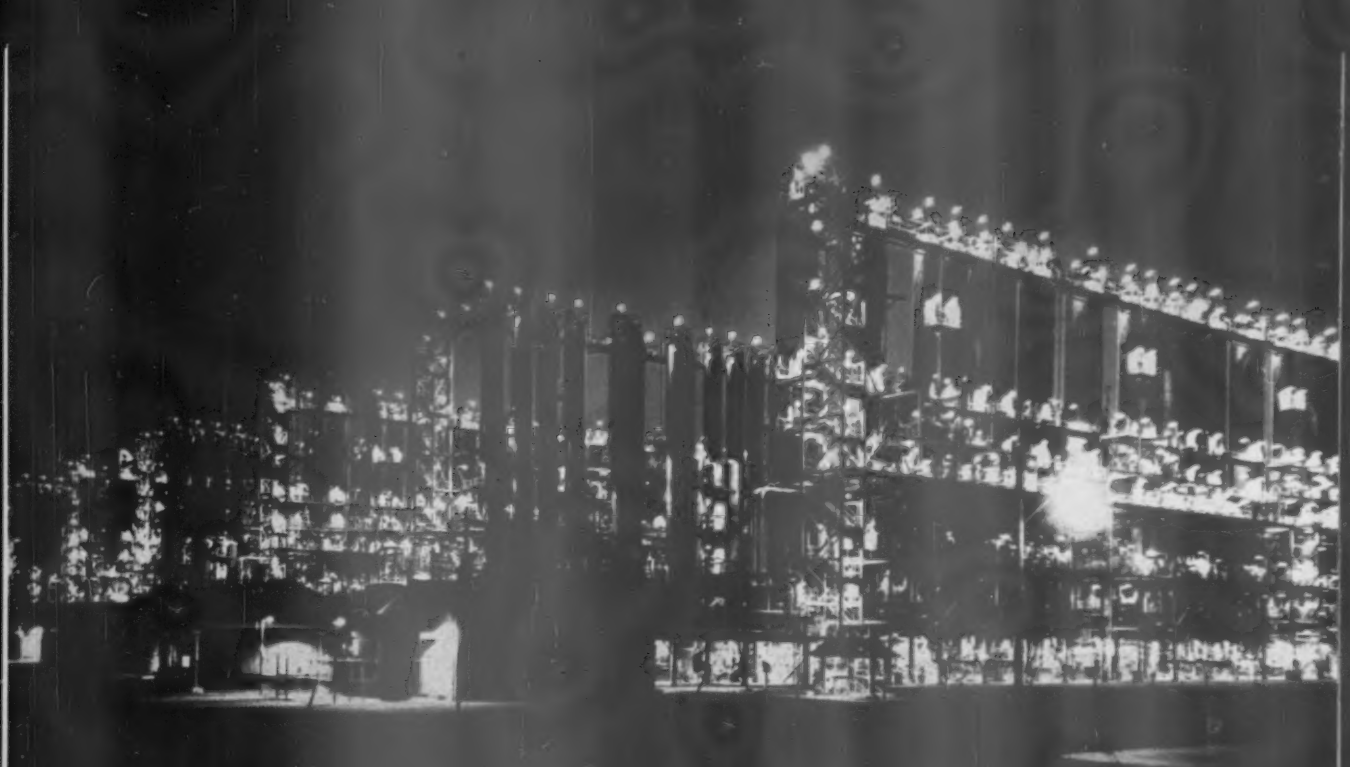


PICKER nuclear instruments

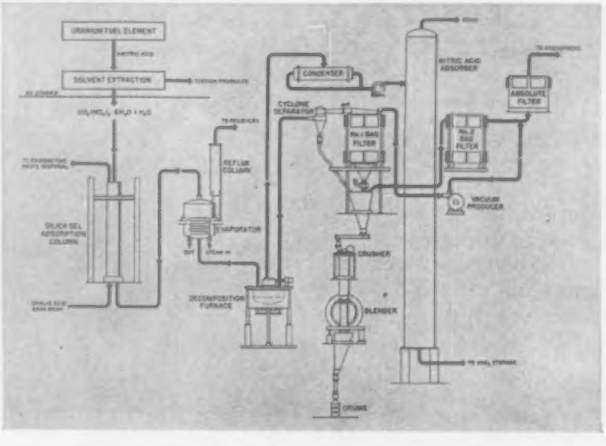


LUMMUS DESIGNS, ENGINEERS, CONSTRUCTS FOR THE NUCLEAR INDUSTRY

Heavy Water Area, Savannah River Plant. Lummus handled design, engineering, procurement and construction liaison of this area.

World-wide designers, engineers and constructors of over 800 major plants for the process industries in the last half century, Lummus now offers its experience for the development of atomic energy installations. Here are some current examples of Lummus work in this field:

Uranium Oxide Recovery Unit of the Savannah River Plant. Lummus handled design, engineering, procurement and construction liaison of this unit.

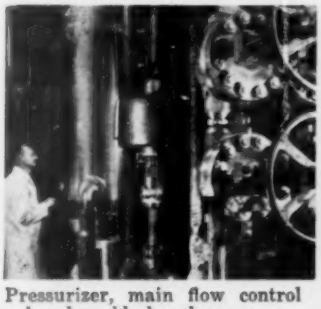


Nitric Acid Recovery Unit of the Savannah River Plant Chemical Separations Plant. Lummus handled design, engineering, procurement and construction liaison of this unit.

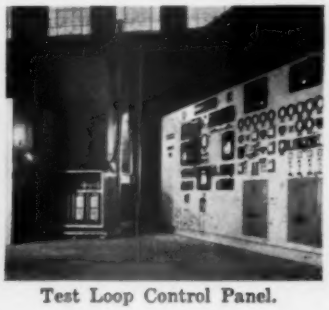
Plant engineered and designed by Lummus for Beryllium Corporation to extract beryllium metal from beryl ore.

Ore sintering furnace used to produce beryllium metal.

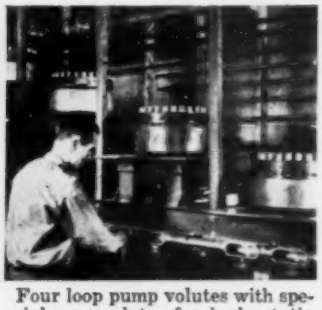
Below is the high pressure, high temperature test facility, constructed by Lummus at its Engineering Development Center for the Knolls Atomic Power Laboratory. The facility consists essentially of a pressurized water heat exchange system and demineralizing equipment. Reactor fuel and materials samples are inserted in the in-pile test section for study under controlled conditions of temperatures, pressure, radiation flux, and water conditions.



Pressurizer, main flow control valve, loop block valves.

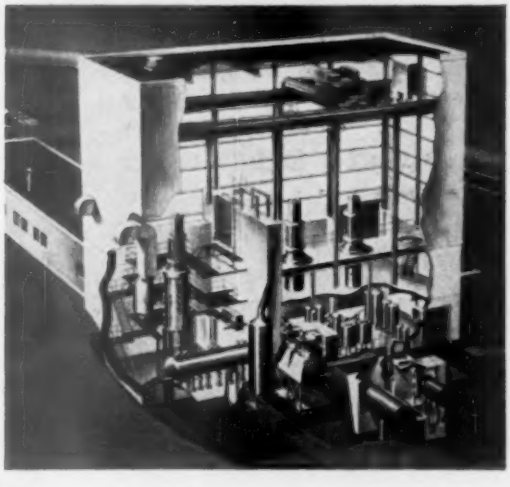


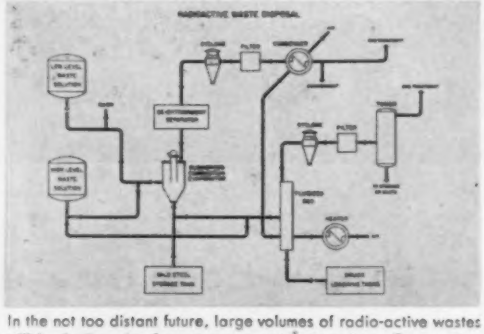
Test Loop Control Panel.



Four loop pump volutes with special cover plates for hydrostatic testing.

This high temperature test facility was designed and engineered by The Lummus Company under sub-contract to Westinghouse Electric Corporation, Bettis Atomic Power Division. Its purpose is to make criticality measurements and to determine flux distributions in water moderated reactors operating at low power levels and elevated temperatures and pressures.





In the not too distant future, large volumes of radio-active wastes will be forthcoming from power reactor operations. Great quantities of this material are now being stored in costly underground tankage. We believe that it would further reactor development to have a more economical and safe waste disposal system to take care of the large radio-active waste volumes. The Lummus approach to this has been directed toward utilizing known engineering techniques which require special consideration due to the unique problems associated with radio-active waste.

Lummus' extensive experience in evaporation, entrainment, condensation, fluidization, material handling and other unit operations, is available to design and engineer radio-active waste disposal systems of the type shown here.

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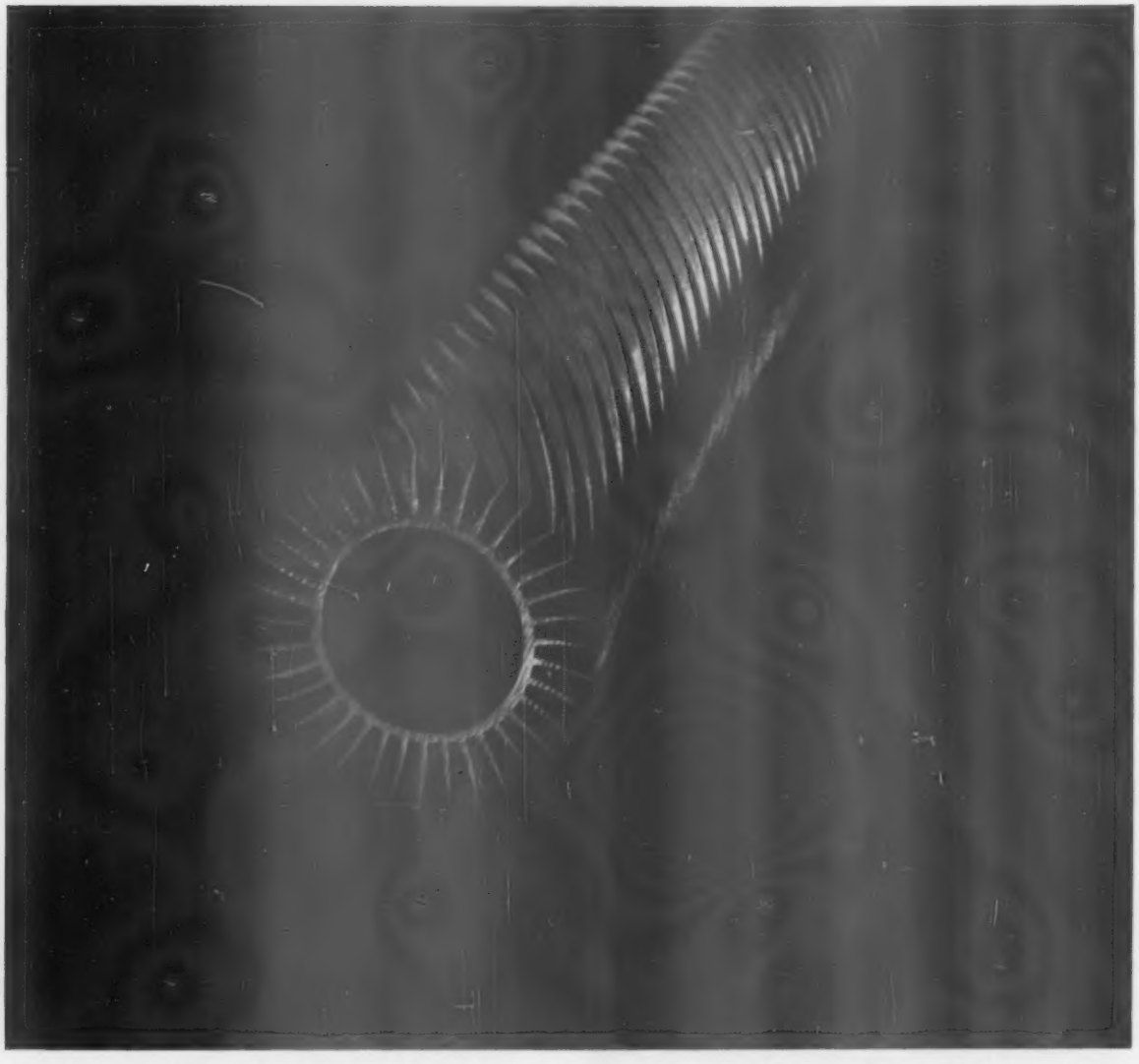

Magnesium alloy fuel-element can, developed for the British nuclear power stations. Other types of can are also being produced in aluminium, stainless steel, niobium and vanadium for nuclear reactors.

The know-how on gas-cooled reactors

When, some seven years ago, we in Britain began to develop nuclear power stations, we were forced by circumstances to adopt what seemed an unpromising type of reactor—gas cooled, graphite-moderated, fuelled with natural uranium. Many people were pessimistic. We thought we could make the thing work—and Calder Hall proved better than we dared to hope.

Calder Hall was designed primarily to produce plutonium with electricity as a by-product. The new reactors at Berkeley, Bradwell, Hunterston and Hinkley Point are designed for power production. They can thus be made more efficient, lower in capital cost per kilowatt, and simpler and cheaper to operate.

In all this work—and in much more that went before it—the companies of Tube Investments Limited have had a part. They have, in fact, been involved in many branches of atomic energy development from the beginning. But on components for gas-cooled reactors in particular, T.I. scientists and engineers reckon to know as much as anyone. Their experience is available to assist you.

Other products include:—Finned heat exchanger tubes · Rare metal components · Engineered reactor components such as:—Control rod, graphite restraint and stand pipe assemblies · Neutron sources.

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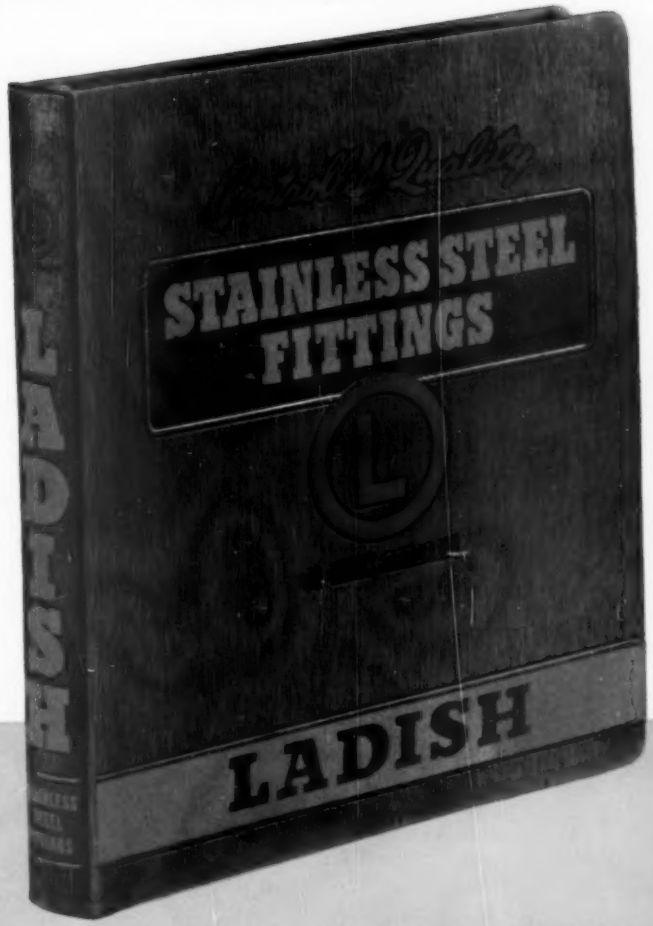

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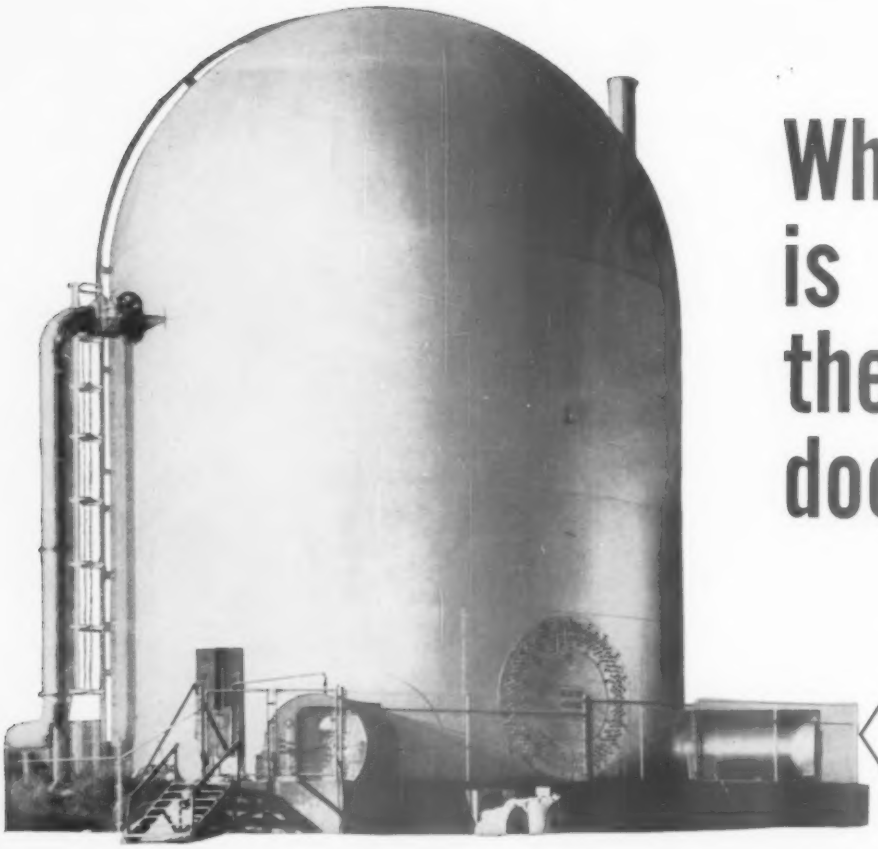

Where is the door?

These two tubular entrances are the Pratt Air Locks in the Vallecitos Boiling Water Reactor at the General Electric Vallecitos Atomic Laboratory at Pleasanton, California.

The Henry Pratt Personnel Air Lock

provides easy passage in and out of containment vessels in full compliance with the AEC code for reactor construction.

While the Air Locks are designed and built specifically for each atomic power plant, they all include some very desirable Pratt developments.

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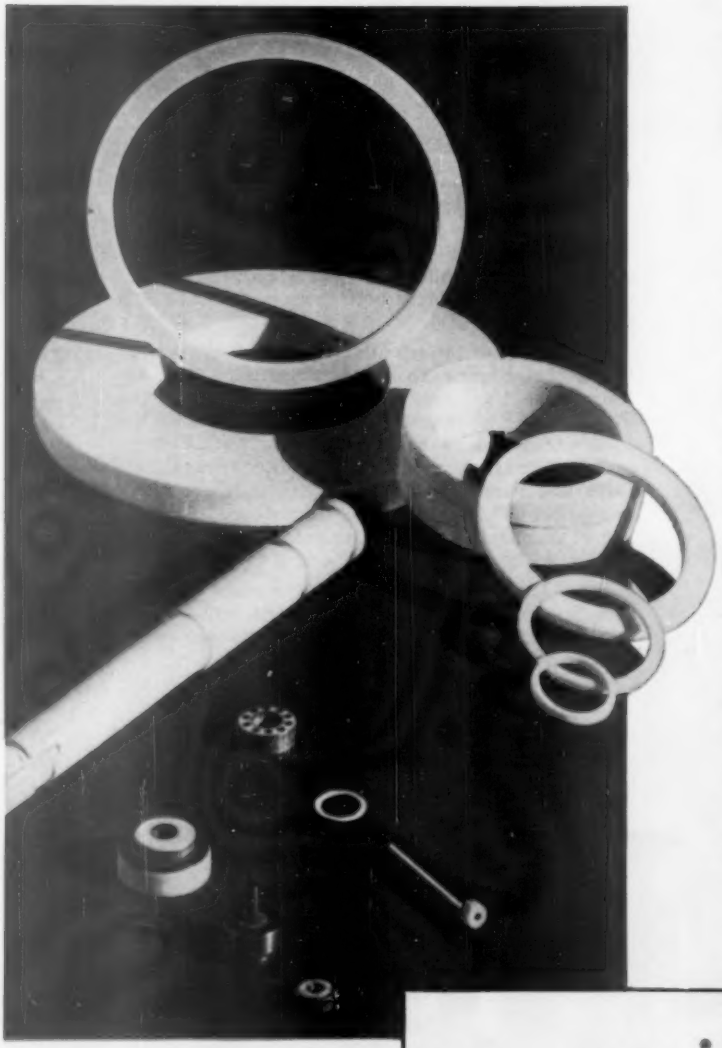

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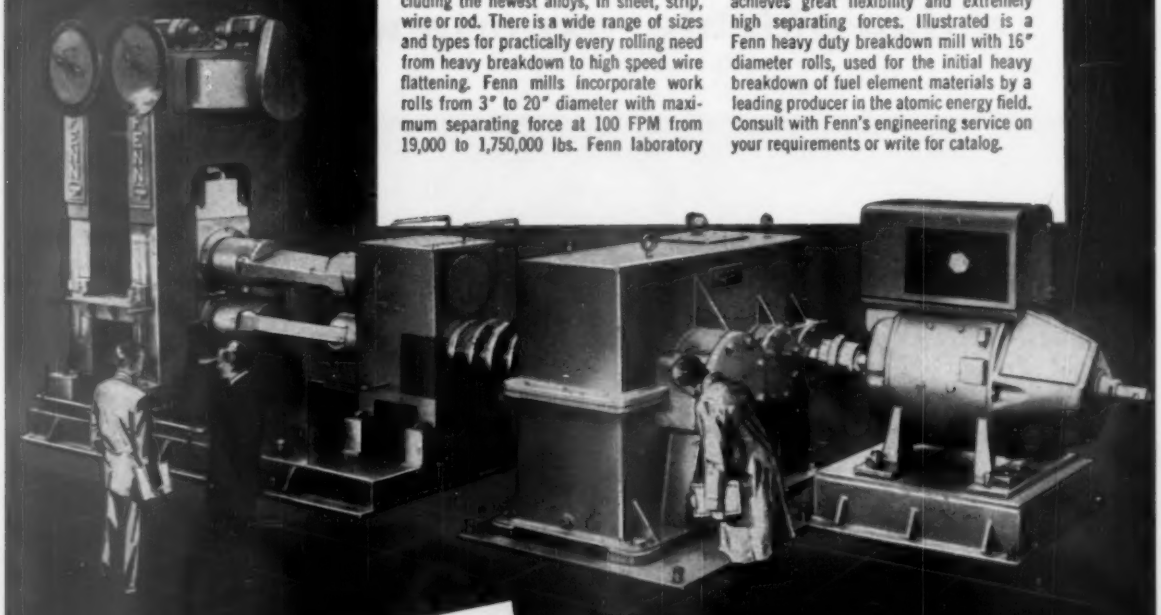

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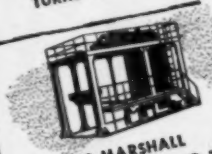

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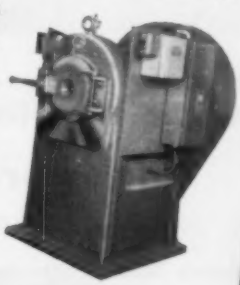

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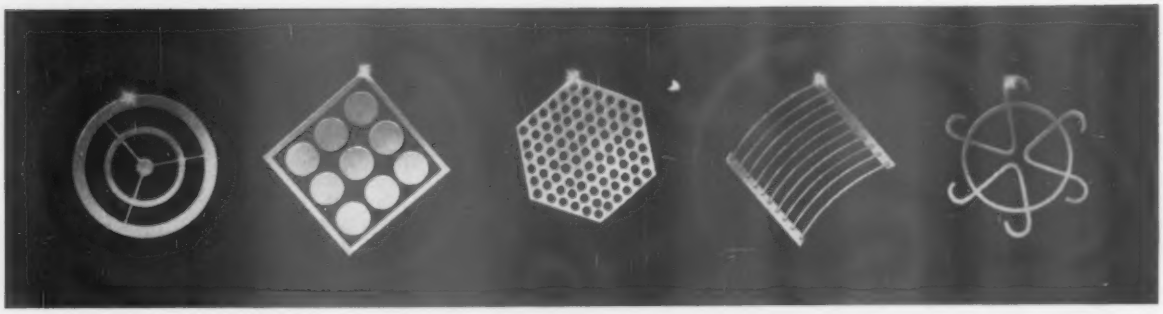

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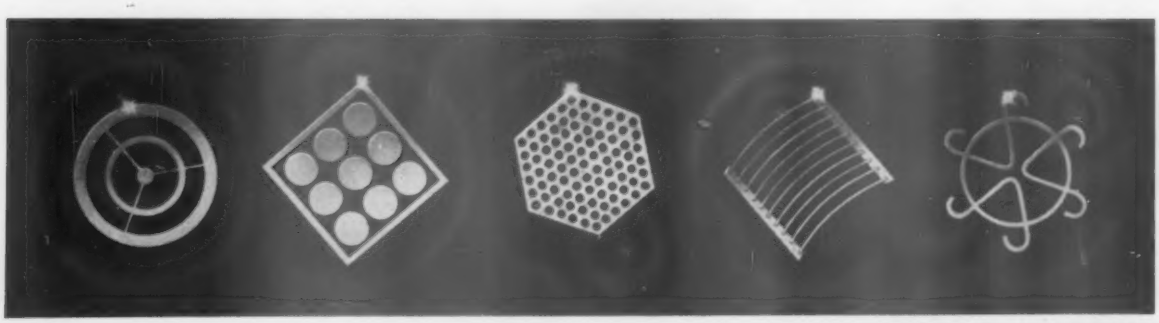

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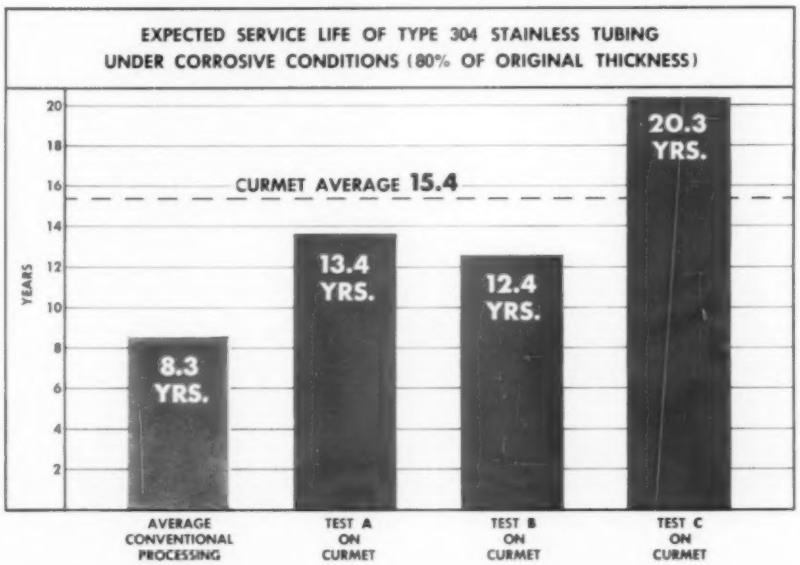

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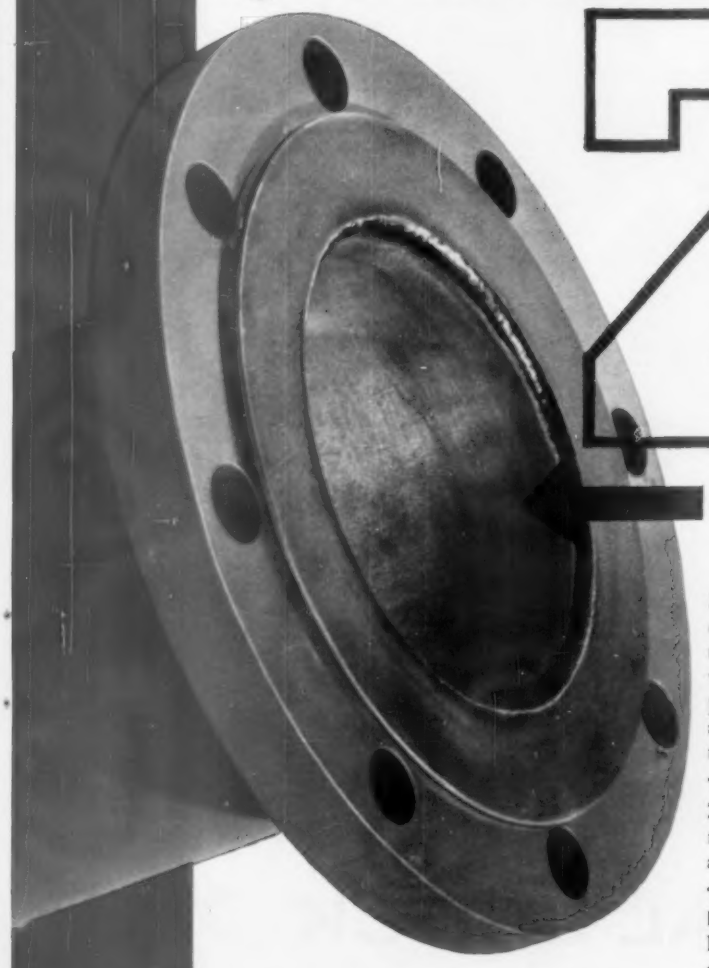

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on the inside

(mild steel on the outside)

Zirconium liners are now available for a variety of basic processing components such as "T's", columns, tanks and reaction vessels. These liners provide all the versatile corrosion-resistance and outstanding nuclear properties of zirconium at surprisingly low cost. Rapid advances in zirconium manufacturing and fabrication techniques offer greater savings for:

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Zirconium's low neutron absorption and corrosion-resistance to coolants permits more economical fuel applications in almost every reactor design.

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Dual resistance to corrosion...zirconium protects against either strong acids or caustics. Versatility means interchangeability and longer lasting system components.

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Write today **for complete price schedules on all zirconium products.**
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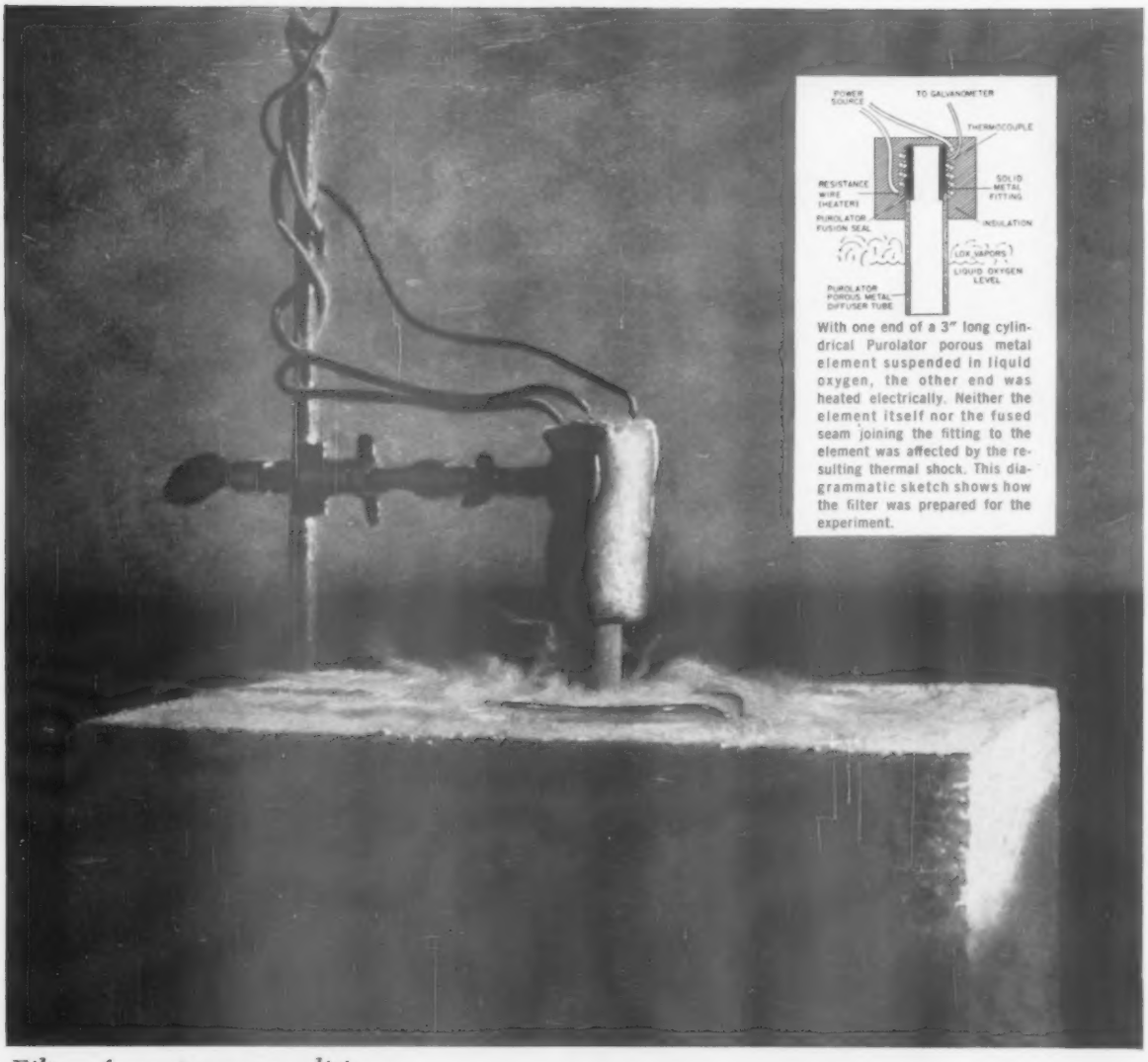
Production Pioneer of ZIRCONIUM

CARBORUNDUM

91-807 - A



With one end of a 3" long cylindrical Purolator porous metal element suspended in liquid oxygen, the other end was heated electrically. Neither the element itself nor the fused seam joining the fitting to the element was affected by the resulting thermal shock. This diagrammatic sketch shows how the filter was prepared for the experiment.

Filters for extreme conditions . . .

THERMAL SHOCK

Purolator metal filter media can take it

How much thermal shock can a filter withstand?

In a recent series of experiments, various samples of Purolator metal filter media stood up under temperature gradients, across short lengths, of up to 500°F...and could have taken more. There was no effect on filter efficiency.

Thermal shock is only one of the difficult operating problems Purolator's staff of "Q" and "L" cleared-filtration experts handle regularly. They can design and produce the exact filter needed to remove any known contaminant from any known fluid under any operating conditions. They have produced filters and separators to operate within the following wide ranges of conditions:

TEMPERATURES: from –420° to 1200°F.

PRESSURES: from a nearly perfect vacuum to 6,000 psi.

RATES OF FLOW: from drop by drop to thousands of GPM.

DEGREES OF FILTRATION: from submicronic to 700 microns (in various media).

No other filter manufacturer can offer such complete services to handle so wide a range of tough operating conditions. These brochures outline what Purolator can do for you, or, if you have an urgent filtration problem, call Jules Kovacs, Vice President in charge of Technical Sales... or send him the details of your application.

Filtration For Every Known Fluid

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PRODUCTS, INC.

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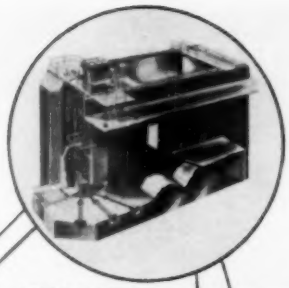
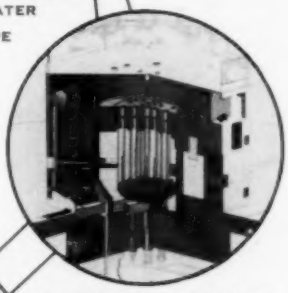
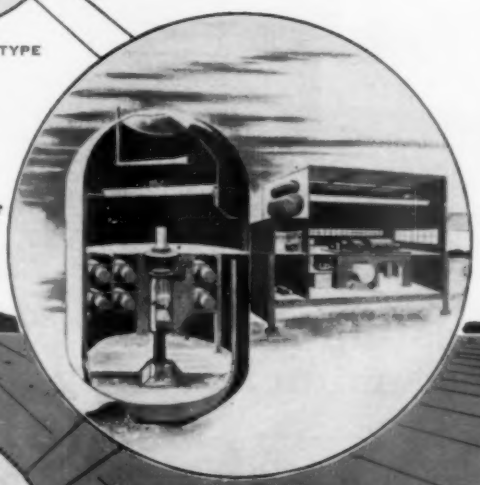


LIGHT WATER
POOL TYPE



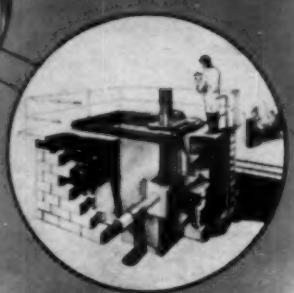
HEAVY WATER TANK TYPE

LIGHT WATER TANK TYPE



BOILING WATER POWER REACTOR

PROCESS HEAT REACTOR



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- **Nuclear physics calculations**
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For more information on how ACF can help you solve your nuclear problems, write to:

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Division of ACF Industries Incorporated
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WESTINGHOUSE TESTING REACTOR

The Testing Reactor Is Fast Becoming a Reality

The reactor vapor container in the foreground is almost complete.

The primary head tank and the process building housing the primary loop equipment, plus the service building housing the reactor control room, "hot cells" and laboratories, have been under construction and appear to the left and right of the vapor container.

By the spring of 1959, this 20-mw reactor will be available to industry for high-flux irradiation experiments, including those conducted under high-temperature, high-pressure conditions. Auxiliary services will include: hot cells, rabbit tubes, reactivity measuring, critical experiment and gamma irradiation facilities.

For contract reservations and assistance in planning nuclear materials tests, write: Westinghouse Testing Reactor, P.O. Box 1075, Pittsburgh 30, Pennsylvania.

Photo taken August 29, 1958. J-59004

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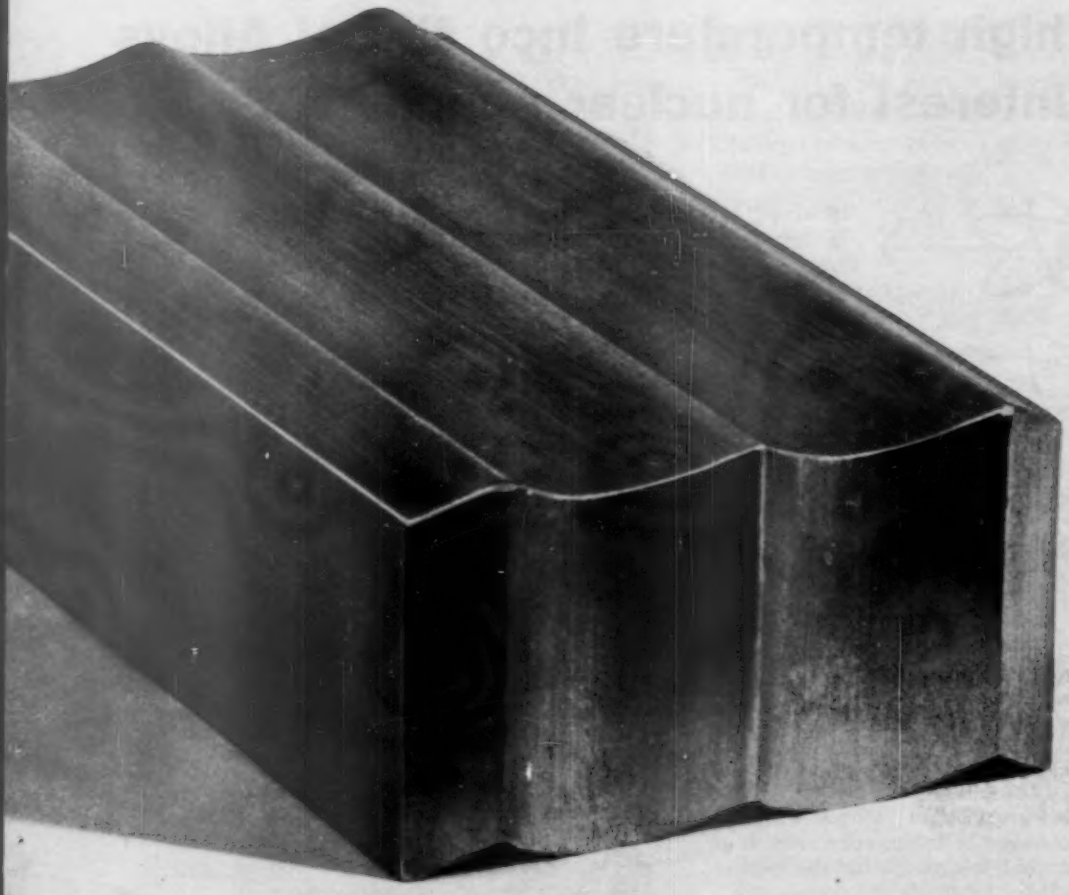
Interlocking lead brick and other unique lead protective products **have been designed by Federated for the nuclear industry. Convenient lead containers, one pound to 10 ton casks, and larger to your precise specifications. Federated is long experienced in fabrication of cast, rolled and extruded lead products, sheet, plates, and piping. Asarco's Central Research Laboratory offers a wealth of information about temporary and permanent structures to house or transport radioactive materials. For lead protection call one of the convenient offices of Federated Metals Division of American Smelting and Refining Company, 120 Broadway, New York 5, N. Y. In Canada, Federated Metals Canada, Ltd., Toronto and Montreal.**

FEDERATED METALS DIVISION OF



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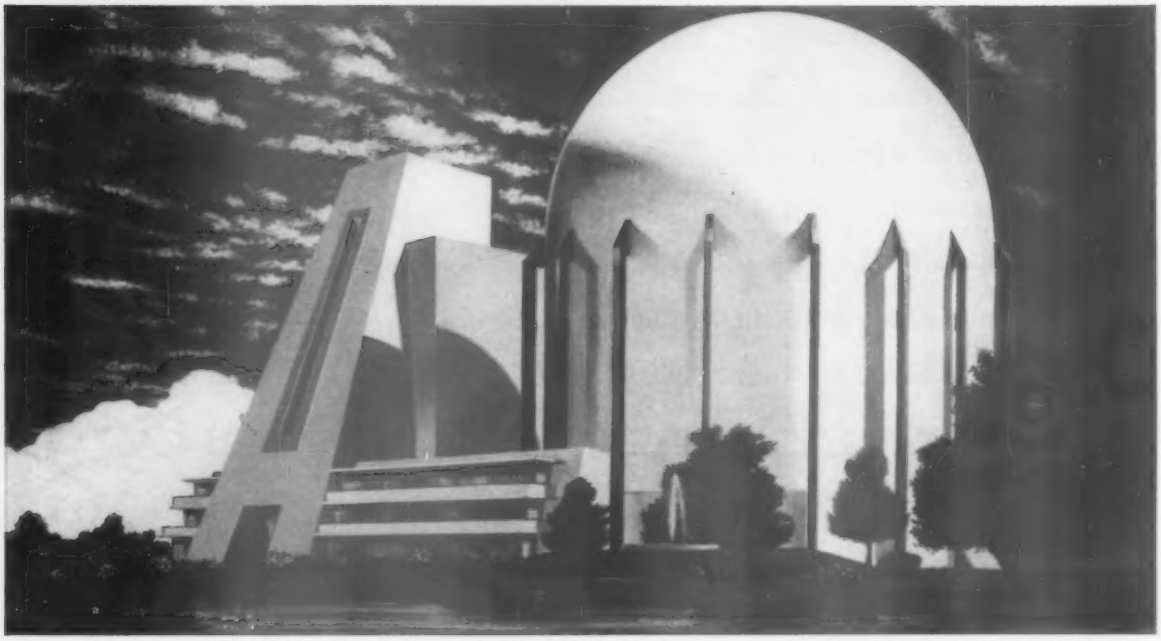
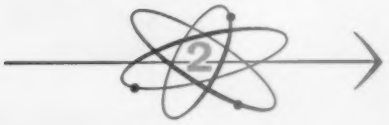
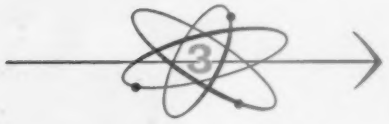


4 new high temperature Inco Nickel Alloys of interest for nuclear applications

Incoloy "T"* titanium-containing nickel-iron-chromium alloy – a modification of Incoloy* nickel-iron-chromium alloy with improved tensile and rupture properties. Has excellent oxidation resistance up to 1600°-1700°F.



Incoloy "901"* nickel-iron-chromium alloy – matches the mechanical properties of Inconel "X"* age-hardenable nickel-chromium alloy at temperatures up to 1350°F.



Inconel "702"* aluminum-containing nickel-chromium alloy shows exceptional oxidation resistance with moderate strength at high temperatures (2000°-2400°F).

Inconel "713C"* nickel-chromium cast alloy has outstanding rupture strength at 1700° and higher, good resistance to thermal shock, and good castability.

*Registered trademark

Want more data on these new Inco Nickel Alloys? Shapes and sizes of stock? Can you use technical help in solving problems of metal corrosion, high and low temperatures? It's yours for the asking.

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NUCLEONICS
ATOMIC POWER
NUCLEAR ENGINEERING
APPLIED RADIATION

OCTOBER, 1958

Modernizing a Modern Industry

On pages 65–68 of this issue there appears a special editorial report prepared by the Department of Economics of the McGraw-Hill Publishing Co. on "How Modern Is American Industry?" This report is appearing in all current issues of McGraw-Hill publications. It is part of a coordinated effort to point out to American industry what can be done now by modernization and improvement of plant and equipment to raise productivity and insure profitable growth ahead.

The role of NUCLEONICS in this special project is different from that of its sister publications, which serve established industries, because the nucleonics field is so new and provides little opportunity for modernization in the ordinary sense of the word. However, there are lessons for the young nuclear industry to learn about its operations, its procedures, its facilities. It is in this spirit that the following NUCLEONICS editorial is presented—to assist the industry in a searching reevaluation of its status.

In carrying out this task, we have had the stimulating guidance of a number of the leaders of the industry, for which we are very thankful.

—The Editors

THE dramatic difference between the Geneva conference of 1958 and that of 1955 is that, whereas in 1955 the emphasis was on what would happen *tomorrow*, the exciting significance of the happenings at Geneva last month was the realization that we are, *right here and now*, in the midst of a going technology. This doesn't necessarily mean that the atomic industry has come of age, that it is yet a thriving commercial enterprise. But what it does mean is that we are now in the era of experience. Now, for the first time, we are beginning to develop a real appreciation of *actual* engineering, operating and cost situations.

The big need, of course, is how to translate this valuable experience into the framework for a profitable nuclear industry. Much needs to be done to accomplish this but the directions, at least, are becoming clear.

The 6 keys to success, as NUCLEONICS sees it, are:

1. Experience
2. Boldness and imagination
3. Ingenuity
4. Investment foresight
5. Mature business sense
6. Adequate facilities

The nuclear industry needs all these things in large doses. To see how they apply, we must first examine the historical development of the industry.

Modernizing a Modern Industry

SURPRISINGLY, the sheer size of the U. S. atomic energy program has in some ways worked against the logical and sensible development of a strong industry. For one thing, maturing of the industry has been slowed by the dominant and paternalistic attitude of the government. And the industry has not helped itself any by some of the ways in which it has comported itself.

Take the manufacturers of nuclear instruments, for example. This was probably the first true industrial activity to come along right after the Manhattan Project terminated. A number of small companies were started by bright young technical men who had gotten good experience during the war. And many of them thought that all that was needed to turn a profit was just some good ideas. They learned the hard way that this wasn't so. Among other things, they underpriced their products. In many cases, this resulted in their turning out equipment of poor quality. Also, some spread themselves too thin by producing too many products.

It wasn't until many years later that many of these companies recognized that, in addition to technical competence, they couldn't do without mature business judgement. They learned that there wasn't something magical about atomic energy that automatically assured success.

All this was unfortunate because a real market potential has existed in nuclear instrumentation almost right from the start.

On the other hand, in the power-reactor sector of our industry, the situation has been totally different. The major difference is the fact of the lack of immediate economic need for nuclear power within the U. S. This has pretty much meant that there has been a total lack of urgency about the program. The government has dominated the field and has called most of the shots according to how it decided to spend its money.

Industry has not done enough thinking for itself, has not used enough of the imagination that it uses in nonnuclear industry. This has resulted in one major pitfall—many companies have decided that the way to get into the power-reactor and power-reactor-component business is to "buy" their way in. This has brought in companies without adequate facilities or knowledge, companies that have been attracted by the public relations value and glamour of being in atomic energy.

Not only has this hurt the "buying-in" companies, but it has also damaged the rest of the industry. In fact, as a result, normal competitive factors have not yet emerged in some phases of the industry.

AN additional harmful effect of this is that if an economic power reactor is developed within the next few years for service in the U. S.—some feel that this is a definite possibility—the existing facilities of the competent suppliers will be completely inadequate to meet the technical and production requirements of the new industry in less than a decade. To prepare for this eventuality we must do everything we can during the next few years to generate enough business to keep the capable manufacturers going—and growing.

But "going and growing" is not enough. Irrespective of the amount of income that any one company may have, a lesson that has been learned in the first decade of the nuclear industry is that, as a business, atomic energy is not much different from any other business: it needs mature management judgement and hardheaded and practical engineering considerations. Fortunes will not be made overnight. Many old companies have lost millions learning this lesson and many new companies have not survived the lesson.

This does not mean, however, that companies with technical skills in other industries will be successful in stepping into the nuclear field simply because they have been successful elsewhere. Rather there is the need for specialized skills and facilities. One manufacturer has told NUCLEONICS: "Critical facilities, test reactors, hot cells, computers, high-quality experimental shops and various test loops and rigs are some of the most important . . . development tools that are at the source of the nuclear manufacturer's reason-to-be. We, as a company, already have a substantial investment in these facilities. It will be necessary to continue to expand and modernize them and we do have such plans. We look to these facilities to continue the development of our 'know-how' and to keep us ahead of the competition."

Although the government has been carrying the major share of the burden of research and development in atomic energy, industry cannot afford to stand on the sidelines and merely look over the shoulders of the government laboratories. It will be through research and development that experience and techniques for cost reduction will come about.

AND the industry is one in agreeing that its first and paramount need is cost reduction. One veteran manufacturer has pointed out to NUCLEONICS that, experienced as they are in conventional manufacturing, they have found that specific experience in nuclear manufacturing has enabled them to drop costs by 20% on certain components, without any tooling change.

The editors here present some reflections on the state of the nuclear industry

Modernizing a Modern Industry

This same manufacturer feels that working toward automation should help reduce costs although designs are too fluid to justify the complete investment required by modern high-volume manufacturing methods.

Everyone agrees that there should be considerably more work than is now being done toward the use of more common engineering materials—and making today's exotic materials common.

When industry leaders contemplate the problems of the field, they are by no means entirely introspective: there is much also that they feel the government—that is, AEC—could do to improve the situation.

BUT above all they feel a more aggressive government policy in atomic energy is required to provide the business and the stability so badly needed. The industry's craving for more leadership from Washington was made patently clear in the NUCLEONICS survey of last winter (NU, Feb. '58, 17).

Also, with a maturing on the administrative side should come an easing of the requirements on industry. Among the specific shortcomings AEC was charged with were these:

- Imposing too heavy a burden on industry in terms of time delays and red-tape demands in the process of assembling the hazards-evaluation information necessary for a facility construction permit or license.
- Aggravating the situation regarding companies "enticed in by the glamour of the atom" by accepting bids in many instances from unqualified vendors.
- Conducting contract negotiations inefficiently, sometimes to the point of being self-defeating. Examples are cited where a bid to AEC was made on the basis of cost estimates founded on subcontractors' prices for essential parts, the latter price being firm only for a limited period. By the time AEC decided to accept the prime contract, the secondary prices had been withdrawn and raised due to escalation on the conventional items involved, whereupon AEC reopened the discussion from scratch, and the same process was repeated. Such a vicious circle can lead to mutual frustration, to bitterness, and to a cost for nuclear power more uneconomic than it need be even at this stage.

THE lack of urgency that underlies our nuclear power development effort has fostered an attitude of technical conservatism at all levels of the industry, from the engineer at the drawing board to the government administrator. Because time has not yet become precious, we tend to fall back on the security of overdesign rather than trust our engineering judgement to work closer to the limits. Thus we insist that our containment shells (which even under the worst circumstances would be taxed to their full design capability only once or twice during a lifetime) satisfy codes for pressure vessels that operate continuously under full load. Similarly, although containment shells or exclusion areas are each reasonable last-ditch safeguards against the usually highly incredible "maximum credible" accident, we still demand that every reactor have both.

Again in engineering our cores we pile hot-spot factor upon hot-spot factor to ensure that we design for the worst possible situation with little regard given to the probability of actually realizing this worst situation.

How much these factors have cost us in needless expenditure of research dollars or, more important, needless expenditure of time is difficult to say. But we can expect that our lack of daring will continue to handicap us in the future in still other ways. For instance there is the danger that we will fall victims to the illusion that our reactor development program will eventually answer all our questions with complete certainty. Ambitious as it is, our program will never be capable of this. The economic performance of reactors is related to our economy in such a complicated way that a satisfactory evaluation of particular concepts may very well be had only by trying them out on a national scale. This means that at some point along the road we are going to have to stick our necks out and choose certain concepts for large-scale development even though our choice be based on incomplete information.

Even to get to this point we will previously have had to have made similar decisions in smaller areas to achieve standardization of fuel-element design, control mechanisms, pumps and so forth. Thus we must prepare ourselves to recognize when we have exhausted the possibilities of research and development on a prototype basis and to have the courage to take the plunge into full-scale programs.

STILL another question we must ask is whether the fundamental premise of our nuclear power program is itself not too conservative—is it really true that we don't "need" nuclear energy today in the U. S.? The reasoning behind this assumption is that we have conventional fuel reserves that will provide us with power at current prices (7 mills, say) for years to come—therefore, we can afford

and on the steps that need to be taken to make it a more profitable one

Modernizing a Modern Industry

to take our time developing nuclear plants that will produce power at this same price. But this arbitrarily sets the goal of nuclear power at 7 mills—there is every reason to believe that ultimately the cost of nuclear power in full-scale operation will be significantly cheaper than today's cost of conventional power (this the British already predict for their plants). Why should we wait to take advantage of this saving? Isn't there a good chance that a really all-out effort to develop nuclear energy *now* would in the long range pay us huge economic dividends, not to mention the advantages for our international foreign policy?

In effect, all our present program asks of nuclear power is that it help maintain the economic "status quo"—painful experiences in other areas during the last year have already taught us that in today's world the "status quo" may not be good enough.

LET us now look at another sector of our industry—one whose importance is too often underestimated—those activities having to do with radiation and its applications. Already firmly established in the laboratory, the use of radiation and its associated technology is finding its place in industry.

For example, irradiation has its place in the laboratory as a scientific and an analytical tool. But both of these technologies have everyday industrial potential that is just beginning to show.

Because radiotracing has already done much, it is altogether too easy to overlook how much more it can do. Without benefit of subsidy the radioisotope program of the AEC has grown in 12 years until about 1,700 organizations are receiving more than 13,000 radioisotope shipments from Oak Ridge each year. Industrial use has nearly doubled in the last three years. These are not small numbers, but they are small fractions of their potential values.

At least two conspicuous avenues are visible for large-scale advance in the use of radionuclides. From an economic point of view both are important because they lead to radiation in industry rather than radiation in the laboratory.

The first of these is the transfer of tracing technology from the laboratory notebook to the plant production schedule. Thickness and density gaging using radiation has already made this step, and its phenomenal acceptance stands as an example for the use of other radiation techniques. Many more radiation methods are available for similar adaptation. Radiotracers that mark pipeline interfaces and activated refinery catalyst beads are forerunners in a system of techniques that are waiting for exploration. Quality tests with radiotracers could become routine.

The second avenue of expansion is the use of tracers by industries that have not yet tried them. It is the usual experience of large corporations that once they have a radioactivity laboratory, it finds a volume of use that is far greater than was predicted. Departments that had no problems for radiotracers to solve suddenly find some when the tracer laboratory is next door.

For the small plant, radiotracers have the same advantage as for big ones. Capital requirements are modest and need be no deterrent. But most small plants are very busy meeting their production schedules with the methods they know. There is no one next door to suggest that a little P^{32} on a wire splice might save a lot of time. The situation offers a large area for expansion. Tracer methods can be expected to spread to ten times the number of plants that are now using them. A little missionary work in the form of wider spread of information or mild subsidy might supply the necessary start.

This second avenue of expansion—getting radiation laboratories into plants that don't have them—looks like the big opportunity as well as the big challenge for tracer technology.

IRRADIATION technology, too, has obvious economic potential. The most conspicuous one is the closing of the gap between radiation costs and values. There are many bits of evidence that the two are close to meeting points in several regions of technology. In a sense, meeting points exist already where radiation is able to do jobs that are impossible otherwise. Examples are production-line drug and pharmaceutical sterilizations in the U. S., the clearance for irradiation of potatoes in the USSR and the likelihood that irradiation will solve the problem of bacterial infestation of frozen eggs imported by Britain.

Above all, one must realize that future expansion in radiotracer and irradiation technologies is not yet clearly delineated in the crystal ball. In old-automobile museums you can look in vain for indications of modern automobile design. The skepticism widely expressed about the airplane in the days of the Wright brothers bears little relation to a world-wide airline schedule. The situation, therefore, calls for optimism as a seasoning for realistic predictions.

The future of applied radiation—and indeed of the entire nuclear industry—belongs to imagination and ingenuity. The challenge is to encourage these two.

The editors here present some reflections on the state of the nuclear industry

PLAN '59

How Modern Is American Industry?

A Report by the McGraw-Hill Department of Economics

THE U.S.A. is starting a new period of economic growth, as we leave behind the recession of 1958. This new period presents a challenge to the nation, to the business community and above all to the individual company – to grow *at a profit*.

By now it is clear that growth is the normal way of life for the U.S. Economy. Since 1947, our national product has been growing at a rate of 3.7% a year. And no recession, even the latest and most publicized, has interrupted the trend for long. Now the economy is growing again.

But the conditions of growth are far different from those that prevailed in the years 1947 to 1957.

Today growth in the economy does not mean pressure on capacity, for most industrial firms. It does not mean easy profits. Rather, this is growth under highly competitive conditions, with profits dependent on a firm's ability to hold down costs. **Is our plant and equipment modern enough to do the job?**

A New Survey

To find the answers to this question, the McGraw-Hill Department of Economics has just completed a special survey of business needs for modernization. **The survey shows that it would cost $95 billion to replace today's obsolete equipment.** And this is a priority job, if business is to get costs down for the years ahead.

This tremendous need for modernization presents a challenge to the U.S.A. as a nation. The Communist powers are making a strong and disciplined effort to demonstrate that they can out-produce us – that they can "plow us under" in a contest of industrial strength.

It is a challenge to American business. Our people expect a continuously rising standard of living. Our workers expect wage increases. And often their demands mean price inflation – unless we can achieve sharp gains in output. The public demands higher national income without inflation. This is the challenge to business as a whole.

It is a challenge to the individual firm. Growth in the economy no longer means an automatic rise in sales and profits for any particular company. There are no shortages; industrial capacity is ample. So to participate in growth, the individual firm must achieve better quality or lower costs than its competitors. Otherwise, there will be no profit in growth and no success story for the company.

Is business prepared today for these challenges? The answer, from our study, is clearly "No". The production and distribution facilities of the U.S.A. are not efficient enough to ensure our continuing superiority over the Communist world, to match every wage increase with higher productivity, to do business in a competitive economy at satisfactory profit to the individual firm.

This statement sounds shocking at a time when much industrial capacity is idle and the recession just behind us is being blamed on a surplus of capital goods. But the facts speak for themselves. Here is the record on the past decade of investment in new plant and equipment, and here is our new study of the job that still remains to be done.

THE MODERNIZATION JOB AHEAD: $95 BILLION

The McGraw-Hill Department of Economics asked a wide sample of manufacturing companies, and experts in other industries, "What would be the cost to replace all obsolete facilities with the best new plant and equipment?" Here is a summary of the estimates. (Details on next page.)

MANUFACTURING AND MINING	$34.3 Billion
PETROLEUM INDUSTRY	5.3
TRANSPORTATION AND COMMUNICATIONS	18.4
ELECTRIC AND GAS UTILITIES	12.0
FINANCE, TRADE AND SERVICES	25.0
TOTAL: ALL BUSINESS	$95.0 Billion

Decade of Expansion[1]

Since 1947, private business in the U.S.A. has invested $291 billion in new plant and equipment. Our manufacturing capacity has increased about 80%; electric power capacity, 145%; capacity for basic raw mate-

[1] Figures on "Decade of Expansion" are for the years 1947-1957 inclusive, except where specific reference is made to preliminary data for 1958.

THE McGRAW-HILL SURVEY OF MODERNIZATION NEEDS

Conducted by the McGraw-Hill Department of Economics in August, 1958

INDUSTRY:	AGE OF MANUFACTURING CAPACITY Percent Installed: Prior to Dec. 1945	Dec. 1945 to Dec. 1950	Dec. 1950 to Dec. 1957	COST TO REPLACE OBSOLETE FACILITIES: Millions of $
Iron and Steel	47%	16%	37%	2,855
Nonferrous Metals	47	13	40	1,022
Machinery	41	21	38	3,224
Electrical Machinery	34	18	48	1,917
Autos, Trucks and Parts	42	11	47	2,204
Transportation Equipment (aircraft, ships, railroad equipment)	59	9	32	854
Other Metalworking	54	17	29	2,351
Chemicals	30	23	47	3,070
Paper and Pulp	49	17	34	2,655
Rubber	46	9	45	600
Stone, Clay and Glass	46	20	34	1,840
Petroleum Refining	45	26	29	1,499
Food and Beverages	58	19	23	3,443
Textiles	59	18	23	1,001
Misc. Manufacturing	51	21	28	6,236
ALL MANUFACTURING[1]	48	19	33	34,771

[1] Includes petroleum refinery companies listed under "petroleum industry" in previous table.

rials, by 55%. The distribution and service industries have increased floor space by roughly 50% in the decade. In 1957 alone, business spent $37 billion on new plants and equipment – more than the combined expenditure in all of Western Europe plus Canada.

But all of this expenditure has not made our facilities as modern as supposed, or as modern as we need. Of the $291 billion invested by business since 1947, roughly $157 billion has been for expansion of capacity. Only $134 billion has been spent to replace old facilities with better, more modern equipment. And in recent years, this investment has not purchased as much new equipment as the dollar figures suggest, because prices of capital goods have climbed.

Our postwar capital investment has repaired the worst of the obsolescence accumulated during the depression and war years. But huge amounts of old equipment are still in use, as shown by the table above. This is based on a survey of the age of manufacturing capacity in several hundred companies, representing all of the major manufacturing industries. Almost 50% of our present capacity was installed before or during World War II. More than 65% was installed before Korea. Expert studies of the major non-manufacturing industries show that the age of equipment, in those industries, is even greater.

Thus, of all business plant and equipment, less than one-third is modern in the sense of "new" since 1950; two-thirds is pre-Korea.

This over-all figure is confirmed by a check on specific industries:

- Nearly two-thirds of our metalworking equipment was installed over 10 years ago, according to preliminary results of AMERICAN MACHINIST'S 1958 census.
- Over 65% of the freight cars on our railroads are more than 10 years old.
- Less than half the capacity to process chemicals, rubber or petroleum is new since 1950 – a period that has seen rapid development in such equipment as automatic controls for these process industries.

These examples take on a dollars-and-cents meaning when we recognize that the latest machine tools are about 40% more productive than 1948 models, and that a combination of new freight cars and modern freight yard equipment can reduce operating costs up to 50%. New instruments, that automatically direct the flow of a chemical (or other raw material) process, can often reduce processing costs enough to pay back the cost of the instruments in one year. These savings cannot be made in older plants. By using obsolete facilities, our industries accept a waste in labor and materials that totals many billions of dollars per year.

Why Productivity Must Rise

The U.S.A. can ill afford this waste. In the economic struggle between the free world and Communist world, our margin of superiority depends on the efficiency of our productive facilities.

For the growth of our own economy, we shall need a sharp rise in productive efficiency. During the next ten years, American business must provide the goods and services required for a population that will increase by 32 million. And the increased population will expect higher living standards. Furthermore, the population in ten years will include a higher proportion of dependent persons – children and retired people – and a smaller proportion of working age men. Thus, with a relatively smaller labor force, industry must provide more goods for more consumers.

At the same time, industry must strive to hold the line against rising costs. In an economy with a tight

labor supply, we cannot count on restraint in wage demands, however desirable such a development might be. In the past ten years, hourly wage rates have increased over 5% per year, nearly twice as fast as output per manhour. And this disparity may well continue – causing still more inflation–unless we make more rapid gains in productivity.

We can make these rapid gains – if industry goes all out to modernize its equipment. Output per manhour (in manufacturing) has increased only 2.5% per year since 1951. But this compares with gains of 4% a year in 1947-1950, and over 5% in the 1920s. Today the machines and techniques are available for us to equal, or exceed, these records – to raise output per manhour at least 5% per year. This is a job that can, and indeed must be done, to assure growth in the economy without inflation.

The Job Ahead

The dimensions of this opportunity are shown by the table on the previous page. In its survey on the need for modernization, the McGraw-Hill Department of Economics asked a wide sample of manufacturing companies how much it would cost to replace *all* their out-dated facilities with the best new equipment available. The Department also interviewed experts in each of the nonmanufacturing industries, to find answers to this question. The answers add up to a staggering bill for new plant and equipment.

Modernization of over-age facilities – replacing only what is really obsolete, by today's production standards – would require a total capital investment of $95 billion, or nearly $20 billion per year for the next 5 years.

Furthermore, new production techniques will soon make *today's* plants obsolete, in many cases. Thus, to keep pace with technical advance *from 1958 on*, will require continuing expenditures of $8 to $10 billion per year for modernization.[1]

The total expenditure to wipe out the backlog of obsolete facilities, and keep up with continuing technical advance between now and 1963, would be at least $135 billion.

The U.S.A. has never spent such a sum on the modernization of industrial facilities. Capital expenditures of boom dimension have, in the past, been associated only with the urgent expansion of capacity. **Some forecasters are now saying that because industrial capacity is adequate, the next few years will be a period of low capital investment. The figures above make clear that this would be a national calamity.** The opportunity is there–and the challenge–to invest record amounts of capital in the modernization of plant and equipment.

A National Problem

This also is a challenge to the U.S.A. as a nation. For 100 years, this nation has been looked to as the model of economic development by the rest of the world. For the first time, we face a serious challenge by another nation and another economic system that claims to be better. In a carefully documented 111 page study released in May, the U.S. State Department declared that "the most serious threat" to the U.S.A. today is the drive for economic supremacy by the Soviet Union.[2] Although a much smaller nation industrially than the U.S.A., the U.S.S.R. is today increasing its national output at a rate of 7% per year and its output per manhour by 4% per year.

The U.S.A. does not have to match these specific figures, which represent the results of forced labor in a country just starting to develop industrially. In the contest to win uncommitted nations, the statistics are not likely to be quoted exactly, in any case. But our over-all growth in national output and living standards must be so impressive as to leave no question of superiority. Our factories must be showplaces of modernization to the foreign visitor that will leave him unable to say "I saw much better" in Britain, or West Germany, or Russia.

This is the challenge to the nation –a political challenge to be sure. But it coincides with the challenge to the business community and the individual firm. And the way to meet it is the same: by thorough and rapid modernization of our plant and equipment – not by the slow and steady pace of recent years, but at an accelerated rate that reflects the greater pressure for output at lower cost.

Obstacles To Be Overcome

We must face up to the fact that real obstacles – both technical and financial–stand in the way of faster modernization. Some companies do not have the technical "know-how" required for the latest production techniques. Many more lack the financial resources. How can we overcome such obstacles, and speed up the replacement of old facilities?

In the course of its study, the Department of Economics obtained comments on these questions from many executives. One of the problems, as we noted above, has been the urgent pressure to expand capacity during most of the postwar period. In giving their attention to this problem, companies have sometimes overlooked the chance to modernize older plants.

In some cases, equipment has been kept in place because it was satisfactory, and the users were not aware of still newer designs. Some equipment users believe that equipment makers are not sufficiently aggressive in designing and demonstrating new models.

The biggest obstacle – and one that presents a persistent problem – is the shortage of funds in many companies that need and want to modernize. For all corporations, the cash flow from retained earnings and depreciation has increased by more than $5 billion from 1953 to 1958. But a number of key indus-

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[1] This estimate is based on technical developments reported by McGraw-Hill editors and current price trends for capital goods. It is consistent with the plans for modernization expenditures in 1958-61 reported by companies in a McGraw-Hill survey conducted in April, 1958.

[2] "The Sino-Soviet Economic Offensive in the Less Developed Countries" – U.S. Department of State, May, 1958.

MODERNIZATION PAYS

Profits on modernization–like all business profits–have come down since 1955. However, modernization, in contrast to new capacity, still offers a relatively quick return on investment. Here are companies' answers to the question: "In cases where you are actually replacing old facilities with new plant and equipment in 1958–how soon do you expect these replacement expenditures to pay off?"

	PERCENT OF COMPANIES ANSWERING			
INDUSTRY:	1 to 2 yrs.	3 to 5 yrs.	6 to 8 yrs.	9 yrs. and over
Iron and Steel	11%	56%	11%	22%
Nonferrous Metals	29	71	0	0
Machinery	12	56	12	20
Electrical Machinery	29	57	7	7
Autos, Trucks and Parts	40	60	0	0
Transportation Equipment (aircraft, ships, railroad equipment)	7	53	20	20
Other Metalworking	38	33	10	19
Chemicals	10	53	21	16
Paper and Pulp	22	22	22	34
Rubber	33	33	34	0
Stone, Clay and Glass	0	57	36	7
Petroleum Refining	16	50	17	17
Food and Beverages	16	44	12	28
Textiles	37	47	5	11
Misc. Manufacturing	9	52	13	26
ALL MANUFACTURING*	18	50	14	18

**Note:* Answers to a similar question, in a 1955 McGraw-Hill survey, were as follows: 1-2 years: 17%, 3-5 years: 64%, 6-8 years: 11%, 9 years or more: 8%.

tries have failed to keep pace with the general trend. **These include some of the areas where the need for modernization is most urgent: the railroads, large sections of the textile industry, some mining industries and many small to medium-size companies in manufacturing generally.** The problem of these industries and companies has grown more acute in 1958 – since their profits have declined much more than the average for all business.

Any plan to step up the pace of modernization generally must deal with the special situation in these problem areas. Depressed industries and companies need outside help, if they are to modernize. Such help would include a stronger flow of technical information and advice (and occasionally, venture capital) from the more prosperous, inventive industries – as well as advice from equipment suppliers and distributors, industrial publishers and consultants. There is also a public responsibility to help in the problem areas–not with handouts of government money, but with technical assistance and help in finding private capital (like the efforts now being pursued by the Small Business Administration).

Certainly we should lose no time in reforming those provisions of the federal tax laws that now impede investment in modern equipment by hard-pressed firms – especially the outmoded and unfair restrictions on rates of depreciation for tax purposes. At present, the tax regulations require that depreciation be computed over relatively long periods of "useful life" for most types of equipment. And this is a primary reason for the lag in modernization. Machinery generally becomes obsolete long before the expiration of its "useful life" as specified in tax regulations. But it is difficult for companies – especially small companies – to set aside cash for rapid replacement, unless the full amount to be set aside is exempt from income tax. Canada and most European nations allow more rapid depreciation for tax purposes than does the United States.

A combination of self-help with technical help, and a fair break from the tax laws, would do much to reverse the spreading tide of obsolescence in depressed industries, and in many small companies.

PLAN '59

It is this combination that McGraw-Hill advocates as "PLAN '59", to help business modernize *now* for growth and profits. This is what it will take to make a start in 1959 on the $95 billion job of modernization, disclosed by the study we have just completed:

1. A better flow of technical information on where and how to modernize business plants and equipment.

2. Careful review by the individual company of its own opportunities to modernize at a profit – then action to replace obsolete facilities.

3. Reform of the tax laws, to allow more realistic deductions for depreciation, and permit more companies to finance adequate modernization programs from this source of funds.

Much of this program is already underway. The 34 McGraw-Hill Publications, and many suppliers and distributors of industrial equipment, have stepped up their information programs to start the modernization drive. Preliminary plans of manufacturing companies show a strong emphasis on capital spending for this purpose. In August, Congress passed a bill providing limited tax relief for small business.

But the real task of modernization still lies ahead. It is the greatest challenge, and the greatest opportunity, confronting American business as we move forward into 1959.

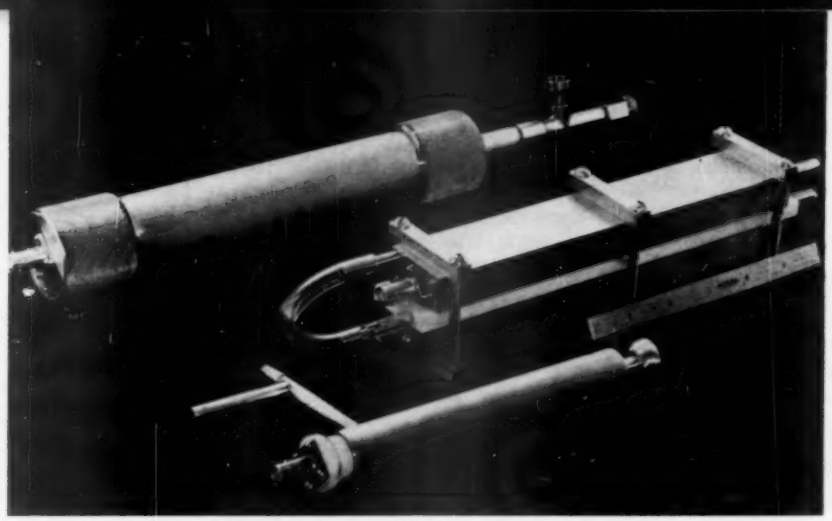

FIG. 1. New proportional-counter designs: top, vapor counter for batch samples; center, window vapor-flow counters; bottom, internal vapor-flow counter

New Proportional Counters for Gases and Vapors

New proportional-counter designs simplify this inherently sensitive tool for assay of C^{14} and H^3 and extend its use to gas-flow applications. Comparison is made with the sensitivity and convenience of other systems

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A COUNTING SYSTEM that is inherently more sensitive to soft beta radiations than ion chambers and simpler than scintillation devices, as well as being cheap and easily adaptable for continuous flow-sample counting, would be expected to come into general use for a wide variety of applications. Yet such a technique, the proportional counting of gases and vapors, has been known for a considerable time but has received only a limited acceptance, and this for "batch" radioassays.

The inherent simplicity of flow-sample proportional counting has been virtually unexploited. Recently several investigators (*1–4*) have conceived the idea of coupling various flow counting systems to vapor chromatographic apparatus. This provides an impressively simple system for simultaneous mass and radiotracer assay of any of the large numbers of compounds that are susceptible to vapor chromatographic analysis. Proportional counters are particularly suited to such application, but there has been considerable reluctance to use them because of their past reputation of unreliability.

Until a few years ago the lack of sufficiently sensitive and reliable amplifier-scalers was the chief difficulty. Now, however, there are several commercial sources of such instruments.

The remaining stumbling block seems to be the undependable behavior of the gas counters themselves. For instance, the commonly used glass-envelope silver-cathode counters are extremely prone to the development of noise even when considerable care is taken to prevent this. Furthermore, the ease with which they tend to contaminate, combined with the near impossibility of effective decontamination, makes them impractical for use in flow applications.

New counter designs. Problems of this nature encountered in connection with research on tritium and carbon-14 incorporation into organic molecules prompted the development of some new designs for proportional counters, applicable to almost any work involving assay of labeled gases or volatile liquids. These counters are shown in Fig. 1 and compared to other systems in Table 1.

All the detectors have several simple features in common. A continuous metal envelope forms the wall of each counter and serves as ground and Faraday cage. Center wires attach through a spring and an insulator to this wall and are soldered directly to a high-voltage connector, which con-

nects to a preamplifier or a high-gain (1-mv sensitivity) amplifier-scaler. These features eliminate all noise difficulties. Both internal counters are designed with flat-end geometry to permit determination of absolute disintegration rates without the need for calibration (*5*). All three counters may be completely disassembled, cleaned and reassembled in a few minutes, thus minimizing the contamination problem.

Proportional Vapor Counter

Details of the proportional vapor counter are shown in Fig. 2. Essentially it is a refinement of counters developed at the University of Chicago (*6*). Robinson (*7*) has also reported an improved design of this type.

Plateau characteristics of the counter with a filling of 1 atm of 10% CH_4, 90% A (Matheson P-10) are shown in Fig. 3. The plateau is more than 400 v long and extremely flat. At 125° C plateau slope has increased slightly, but plateau length is still more than 400 v. Although favorable counting characteristics exist up to 200° C, operation of the counter above 125° C is impractical because the Teflon gaskets flow, causing leaks. If operation in the vicinity of 200° C is essential, these gaskets may be replaced by other materials with bettèr dimensional stability. Background of the counter when shielded by 1 in. of lead is 120 cpm, and its efficiency is about 95%. The 5% loss is due to end and wall effects, which are a known function (*5*) of counter dimensions. With these small corrections, the counter will yield absolute disintegration rates without the need for calibration.

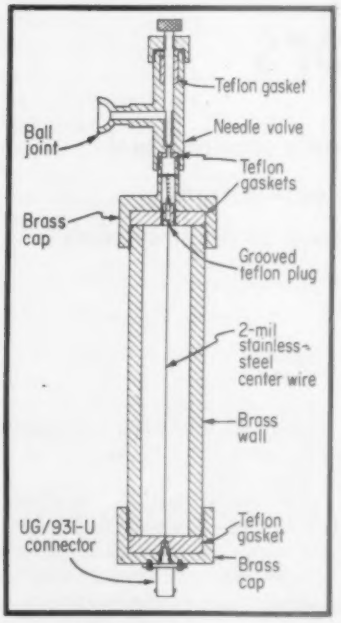

FIG. 2. Details of batch counter. Typical dimensions are 1-in. i.d., 8-in. active length. Center wire is soldered to metal bob resting in hole in Teflon plug; threaded-nylon insulator screws into hole and is joined to spring hooked to metal rod. UG/931-U connector is filled with Shell Epon Adhesive VIII to make it vacuum tight. For decontamination, counter is disassembled by unscrewing stopcock assembly, unhooking center-wire spring, unscrewing end caps and withdrawing center-wire assembly. Counter wall can then be dipped in solvent or scrubbed with soap and water without damage to wire

Most common vapors can be introduced directly into this counter, although some will require the addition of other gases to form a satisfactory counting mixture. The position and length of the plateau will vary with the nature and the pressure of the filling. When using a new type of filling, it is therefore desirable to redetermine the plateau. With a standard external gamma-ray source attached to the counter, this requires but 2 or 3 min. When a quite small sample is available for a large counter, or as a matter of convenience with moderate activities, a common procedure is to put just a few centimeters mercury pressure of the unknown into the counter and to add a large pressure of a standard counting gas (such as P-10).

Some chemicals, notably organic halides, poison counters so that they do not give a plateau. Only very small concentrations of such substances can be counted in the internal counters; these compounds are best assayed by the window counter to be discussed later in this article, or by ion chambers, which are less sensitive to most poisons.

It is worth mentioning that both the internal counters can be operated in the Geiger-Müller as well as the proportional regions.

Vapor Flow Counter

The construction of the internal vapor flow counter is shown in Fig. 4. Plateau characteristics are shown in Fig. 3 at room temperature and at 125° C. Even at 200° C there is a 50-v plateau. However, prolonged operation above 150° C can damage the high-voltage connector. Counter efficiency is about 95%. Background in a 1-in. lead shield is 25 cpm for the counter dimensions shown and varies proportionately for other counter sizes.

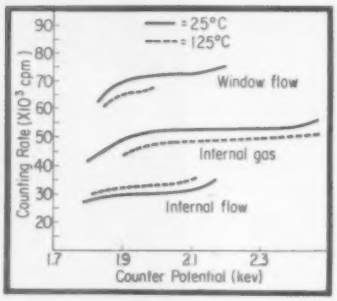

FIG. 3. Counter plateau curves. Counting rates are relative and do not reflect differences in efficiency between different counters or temperatures

The chief use of this counter is in a flow system for the detection of active isotopes in a chemical form and at a concentration not poisonous to the counter. Again, this makes it applicable to most compounds. Being windowless, it is particularly suited to tritium flow work but not limited to this since C^{14} and other isotopes can be detected.

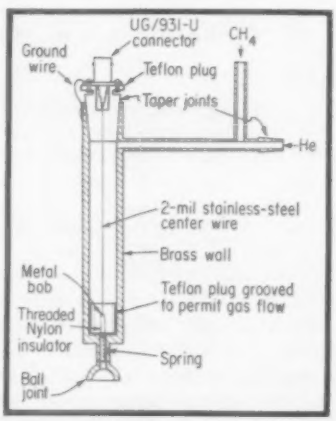

FIG. 4. Internal flow counter. Typical dimensions are ½-in. i.d., 4-in. active length. Center wire is attached as in batch counter; it is helpful to replace ground wire by spring clip, which serves as ground and secures Teflon plug. Center-wire assembly is removed by detaching spring and lifting out Teflon taper joint, leaving counter wall free for cleaning. Branched inlet tube permits introducing two gases, convenient in assaying gas-chromatographic effluents (3); since helium, common carrier for effluent, is poor counting gas, methane is mixed with it. Ball joint at bottom permits attaching cold traps

TABLE 1—Convenience Comparison of Counting Systems

	Liquid scin.	*250-cm³ ion chamber*	*100-cm³ glass proportional*	*250-cm³ metal proportional*	*Ion chamber flow*	*Int. flow proportional*	*Window flow proportional*
Preparation of counting mixture	Multi-component solution	Sample gas only	Gas mixture often necessary		Inject volatile sample into gas stream		
Calibr. requirement	Frequently	Frequently	Occasionally	None	Frequently	None	Occasionally
Use with condensed phase	Usually satisfactory	Can use as windowless counter	Must be converted to gas			—	Can use as solid counter for C^{14}
Suitability for flow assay	—	—	—	—	Fair, resolution often poor	Excellent for nearly all gases or liquids volatile at 125° C	
Temp. characteristic	Not pertinent (*24*)	Poor	Limited by stopcock	Good to 125° C	Poor	Good to 150° C	Good to 125° C
Suitability for use with corrosives	Poor	Good	Poor	Good	Good	Good	Excellent
Noise difficulties	Some	None	Often	None	None	None	None
Discrim. bet. T and C^{14}	Calib. and data analysis required (*25*)	None	None	None	None	None	Excellent, easily done
Construction	Complex	Simple	Simple	Simple	Simple	Simple	Fairly simple
Ruggedness	Light path req. care	Rugged (insulators req. care)	Rugged	Rugged	Rugged (insulators req. care)	Rugged	Rugged
Decontamination	Simple	Simple	Difficult	Simple	Simple	Simple	Simple
Cost	>$6,500	>$1,859	$1,050*	$1,150*	>$1,859	$1,150*	$1,300*

* Includes tank of counting gas, reducing valve, scaler and counter.

In addition to its use in gas chromatography, this counter provides a means of fast routine assay for large numbers of volatile samples by mere injection into a carrier stream of counting gas (e.g., CH_4-He or butane-argon). Care must be taken that the quantity of injected material is not so large as to displace the plateau beyond the high-voltage setting, unless a special circuit that varies the high-voltage setting automatically is used. Sensitivity is such that relatively low levels of gaseous activity can be measured quickly to a standard deviation of 10% or less in just a few minutes (see box, p. 66).

Window Flow Counter

The window vapor flow counter is shown in Fig. 5. It consists of three sections—two identical semicylindrical detector sections hollowed out of brass and a center Teflon sample section.

The sample channel is separated from each of the detector channels by films that are conducting on the detector-section sides. This counter, at some sacrifice of efficiency, thus relieves the sample vapor of the necessity of being all or part of the working medium. A separate counting gas, such as Matheson P-10, flows slowly through the two semicylindrical counter sections and through a bubbler or low-flow meter.

Radiations from the sample flowing through the counter must penetrate the separating foils. The thickness of these films can be chosen to absorb out

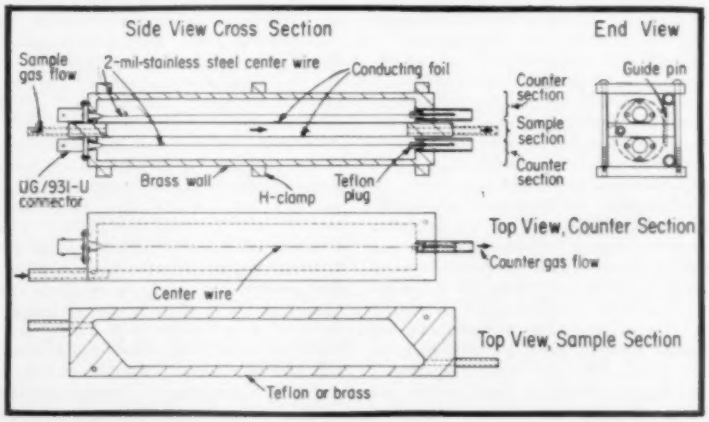

FIG. 5. Window flow counter. Typical dimensions are 7 1 3/16-in. active length, 1-in.-diameter detector sections, 3/16 in. from center wire to foil wall, 3/16-in.-high sample section. Center wires are attached as in Fig. 2. Counter is disassembled for cleaning by unscrewing clamps holding sections together; decontamination of detector sections is not necessary since activity never enters them unless foil ruptures

TABLE 2—Sensitivities of "Batch" Counters

	Isotope	Liquid-scintillation counter	250-cm³ ion chamber	Gas proportional counters	
				100-cm³ glass	250-cm³ metal
A_{min}* (lead shield)	T (dps/mg H_2)	3.2	2.4	2.7†‡	1.2
	C^{14} (dps/mg C)	0.0028	0.084	0.18‡	0.079
A_{min} (anti-coincidence)	T (dps/mg H_2)			1.4†‡	0.55
	C^{14} (dps/mg C)			0.092‡	0.036
Typical efficiency	T	2–30%	95% (22)	85%	95%
	C^{14}	25–90%	63% (14)	85%	95%

* A_{min} is the minimum specific activity (dps/mg) determinable to a standard deviation of 1% in 1 hr of counting time divided between sample and background in the optimum ratio.
† A 30-cm H_2 filling is assumed.
‡ These values also apply to 90-cm³ metal counters.

Calculation of Sensitivities

For calculating A_{min}, the minimum specific activity that can be determined in 1 hr of counting when counting time is divided between sample and background in the optimum ratio, the usual relationship is used (*17*).

Scintillation system. With a scintillation system, such a calculation is complicated by the number of variables involved. Moreover, instrumental limits rather than counting statistics are often decisive. However, statistical considerations can be used to set lower limits.

Typical data for counting tritium in water are those of Hayes and Gould (*18*), who counted 10 ml of 90% alcohol at 2% efficiency with a background of 100 cpm using toluene as solvent. These data are used to obtain the value cited in Table 1. In very favorable circumstances tritium efficiencies as high as 32% have been reported (*19*). However, the advantages to be derived by electronic limitation of background and the difficulty of incorporating tritium into compounds that will not quench fluorescence at high concentrations make the lower efficiency more typical.

For C^{14}, the results of J. R. Arnold (*20*) using his highly sensitive radiocarbon-dating apparatus for determining C^{14} in ethyl alcohol are employed. Here, too, the C^{14} may be incorporated into a compound more compatible with a scintillator solvent than is ethyl alcohol, but with much effort.

Ion-chamber–vibrating-reed electrometer. To determine A_{min} for the ionization chamber-vibrating reed electrometer combination, a relationship similar to that of Sharpe (*17*) is derived from the equations for ion-chamber statistics given by Janney and Moyer (*21*). For tritium, the ion chamber, ion-pair yield per disintegration in hydrogen, efficiency and experimental conditions of Wilzbach, van Dyken and Kaplan (*22*) are assumed. With their reported standard deviation and the Janney-Moyer equations, a background is calculated. This background is then used to calculate A_{min}. For C^{14}, the same ion chamber is assumed, but a yield of 1.5×10^3 ion pairs per disintegration in CO_2 and an efficiency of 63% (*14*) are used. Alpha particle contributions to background are ignored in each calculation since it is assumed that these are subtracted out visually by use of the more sensitive but less convenient rate-of-charge method using a recording potentiometer.

For flow systems we define a sensitivity, A_f, as the minimum activity that must be present in 100 cm³ of gas flowing at a rate of 1 ml/sec to achieve a standard deviation of 10% when background has been counted for 1 hr. A 100-cm³ ion chamber is taken as a reasonable compromise between sensitivity and resolution. The resistance-leak method of determination is commonly used for flow applications, and so α-particle background must now be considered. The Janney-Moyer cosmic-ray background and ion-pair yields for cosmic rays and α-particles, an α-background of 10 disintegrations /hr and a chamber efficiency of 95% for tritium (*22*) and 42% for C^{14} (*14*) are used to calculate a minimum counting rate detectable to 10%. This counting rate is then multiplied by counting time (100 sec), and this value is substituted into the equation of Wolfgang and Rowland (*3*) to calculate A_f.

Proportional counters. A_{min} for proportional counters is determined with the standard relation (*17*). Background values are 120 cpm for the glass proportional counter, 225 cpm for the 250-cm³ metal counter, 120 cpm for the 100-cm³ internal flow counter and 60 cpm for the window flow counter, all in 1 in. of lead. For tritium in the nonflow counter, a filling of 30 cm of H_2 is assumed with 3 cm of argon and 2 cm of ethylene added to give a suitable counting mixture (*23*).

For C^{14} counting in nonflow systems, purified CO_2 at one atmosphere is the assumed counting gas (*15*). Efficiencies are cited in Tables 1 and 2. For flow systems, the calculation is essentially similar to that described for ion chambers.

unwanted radiation, thus providing isotope discrimination. In the use for which this counter was originally designed—the counting of a low activity of C^{14} in the presence of a considerably higher activity of tritium—an aluminized 0.98-mg/cm² Mylar film was used, effectively barring tritium radiation (range 0.9-mg/cm²) (*8*), but passing most of the C^{14} betas.

The plateau of this counter is about 200 v long at room temperature when Matheson P-10 is flowed through the detector sections (Fig. 3). At 125° C the plateau is still a satisfactory 60 v long. Efficiency is a function of counter geometry, foil thickness and penetrating power of the radiation being measured. For C^{14} in the counter of Fig. 5, it was observed to be 30%. Background in a 1-in. lead shield is 55 cpm.

Applications of this counter include determination of C^{14} or any beta emitter of comparable or greater strength in a flow system. Since the sample no longer flows through the detectors themselves but merely passes by them, the plateau is constant, and the counter is not affected by counter poisons. This makes the counter eminently suitable for use by unskilled personnel. Even many ordinarily corrosive chemicals may be used since the sample chamber, being fabricated of Teflon and Mylar, is relatively inert.

In addition, great flexibility in sample-chamber size is possible at little expense, since only the center section of the sandwich must be replaced. By coupling this counter in series with the internal flow counter, simultaneous determination of tritium and C^{14} is feasible. There is the added possibility of using the detector sections separately as a substitute for ordinary end-window flow counters for determining activity in solid samples.

Some limitations of this counter must also be mentioned: Tritium can only be counted through foils so thin (100 $\mu g/cm^2$) as to be hard to handle. Detection efficiency, though quite high, is lower than that of internal counters and cannot be exactly calculated without calibration. The counter is more expensive to fabricate.

Choice of System

Sensitivity, versatility, ease of operation, reliability and cost must all be considered in the choice of a counting system, with experimental conditions

deciding the relative importance of each factor.

The following factors affect batch-counter efficiencies: for scintillation counters, isotope, chemical form, concentration, photomultiplier, temperature and electronic settings; for ion chambers, isotope, chamber size (markedly) and filling gas; for proportional counters, counter dimensions (slightly).

Perhaps the most striking conclusion derived from Tables 1 and 3 is the all-around superiority of proportional counters for all flow applications* involving vapors up to 125° C, except those where such extremely high levels of activity are involved (4,000 cps for our conditions) that scaler resolution time begins to cause severe losses. A 2–25-fold greater sensitivity, faster response, better temperature characteristics, and the ability to handle corrosive C^{14}-labeled compounds all greatly favor counters over ionization chambers. In addition, the counter when used in conjunction with a ratemeter-recorder combination directly provides both an integral (total counts observed on scaler) and differential (recorder trace) record of events. The ion chamber can directly provide only one—the resistance-leak method giving only a differential curve on a recorder trace and the rate-of-charge method only an integral curve. Finally, the relatively slow response of ionization chambers using the resistance-leak method at maximum sensitivity (*12*) makes them even less satisfactory for any application where fast response to relatively low activity is needed.

Nonflow systems. For counting gases in a nonflow system, the choice is less clear cut. The proportional counter offers sensitivity and cost advantages, but has the minor disadvantage of often requiring filling with counting gas.

TABLE 3—Sensitivities of Flow Counters

		Ionization chamber flow	*Internal flow proportional*	*Window flow proportional*
A_f* (dps) (lead shield)	T	50	2.1	Will not detect
	C^{14}	13	2.1	5.6
A_f* (dps) (anti-coincidence)	T	Not applicable	1.1	Will not detect
	C^{14}		1.1	3.9

* A_f is the minimum activity required in dps in 100 cm³ of gas flowing at the rate of 1 ml/sec for detection to a standard deviation of 10% when background has been counted for 1 hr.

Very often the characteristic properties and activity level of the particular sample to be counted must be considered. Thus, for tritium contained in a hydrogen gas sample, there is a decided sensitivity advantage to be gained by proportional counting at the slight sacrifice of having to add another gas to the H_2 to get a suitable mixture.

CO_2 is another interesting example. At the lowest levels of activity (e.g., radiocarbon dating), proportional counters filled with several atmospheres of purified CO_2 are used in conjunction with anticoincidence circuitry (*13*). When activity levels are somewhat higher, an ion chamber is more convenient since unpurified CO_2 may be counted. Finally, at still higher levels of activity where sensitivity considerations are unimportant, unpurified CO_2 may also be used in the proportional counter (up to 5% of the counting mixture may be CO_2). Under these circumstances, the user must weigh the considerably lower cost of the proportional counting system against its need for a second filling gas and its susceptibility to poisons.

Nonvolatile samples. Nonvolatile samples can be converted to gases by standard techniques (*14*).

If the same or very similar liquid or solid samples of large size are to be routinely counted, and if cost is not an important consideration, then a scintillation system is the obvious choice. However, the requirement of solubility in a scintillator solvent, the quenching of fluorescence by some materials and the general variation of counting efficiency with nature and concentration of sample make it less attractive when a variety of samples must be handled.

Though the use of suspensions and gels (*15, 16*) gives some promise of alleviating the solution difficulties, the situation still is such that serious consideration should be given to conversion of these varied samples into CO_2 or H_2.

* * *

It would be difficult to overestimate the assistance to this work from the staff of the machine shop of the Sterling Chemistry Laboratory at Yale. Particular pleasure is taken in acknowledging the contribution of Mr. Edward Ford, who not only fabricated these counters but also made several improvements on the original designs. The authors are grateful for helpful suggestions from Messrs. Thomas Pratt and Richard Armstrong.

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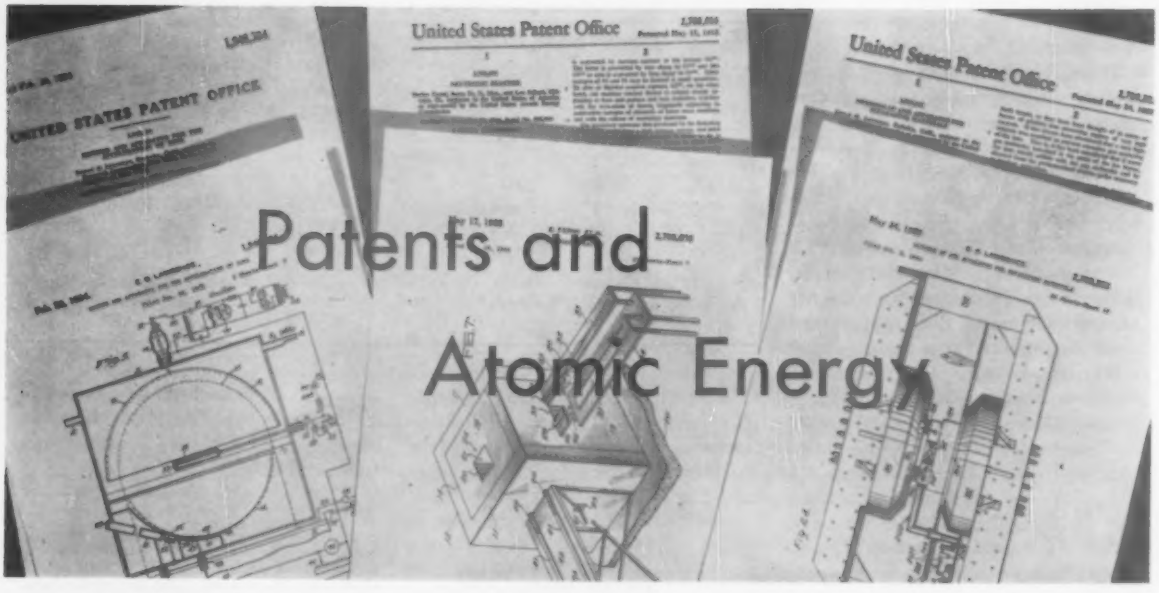
* Scintillation systems are not discussed for gas-flow counting since the source of their great advantage, the ability to utilize condensed phases, is lost in the gas phase. Gas cells in which solid scintillators are embedded in the walls have been constructed for special purposes (*9*), but in general the unfavorable geometry and low efficiency of solid scintillators for detection of weak beta radiation weigh heavily against the scintillation counter for assay of gases. Detection of scintillations in gases themselves is under active investigation (*10, 11*), but application of these techniques to weak beta radiation has not been reported, nor, except in specific instances, does there appear to be any great advantage in such application.



Patents and Atomic Energy

Are you overlooking patents as a source of information on the latest atomic energy developments? A review of landmark patents shows their importance

By ALFONS PUISHES, *Palo Alto, California*

The American patent system has two principal functions. One of these is well appreciated by most people and has been amply exploited by American industry. It is the function set out expressly in the Constitution of the United States, which gives to the Congress the power to secure to inventors the exclusive right to their discoveries in order to promote the progress of science and engineering. Stated succinctly, this is the "incentive" function of the system.

The other, equally important but less appreciated, function has to do with the dissemination of useful knowledge. Indeed, the publication of the description of an invention is the consideration for the grant of the exclusive right in the first instance. This is the "educational" function of the system.

Many have long felt that our patent literature is not sufficiently utilized as a source of technical and scientific information even by those actively engaged in research and development work. This is especially true of the atomic-energy field, which had been shrouded in secrecy for so long, and in which, up to the present time, the normal operation of our patent system has not been permitted to function in its entirety.

With the gradual emergence of atomic energy from behind its wall of secrecy, and the restoration in considerable part of most of the provisions of our patent law in this field, it seems timely to stimulate an interest in the "educational" function of our patent system for workers in atomic-energy.

NUCLEONICS and Patents

As pointed out in the accompanying article, patents are an important means for staying abreast of technical developments. Starting with the next issue NUCLEONICS will bring you the highlights of world-wide developments in atomic-energy as reflected in patent activity. Watch for this new department.

For this purpose, a selection of landmark U. S. atomic energy patents has been made from all the patents that have issued to date. These are arranged, discussed, and referenced by subject matter and generally in the chronological order of development of the art rather than dates of issue of the patents.

1933–1940

The early basic scientific work on subatomic particles and transmutation that took place during the first thirty years of this century was not accompanied by any appreciable amount of patent activity. In fact, it was not until 1934 that the first patent of note was issued to Lawrence for his cyclotron (*1*). This invention was based on the previous work of Wideroe in Germany, although that gentleman did not enter the U. S. patent field with his ideas until much later. The broadest of the 17 claims of the cyclotron patent, which covers both the process and the apparatus, is, among other things, a

good introduction to patent claims in the atomic energy art. It reads:

"The method of multiple acceleration of ions which comprises subjecting ions to repeated accelerating action of an oscillatory electric field, and deflecting the motion of the ions by the action of a magnetic field to cause the ions to revolve in curved paths in the electric field, the revolutions of the ions being in resonance with the oscillatory electric field, to effect cumulative acceleration of the ions."

The discovery of the neutron by Chadwick in 1932, and the related work of Fermi, resulted in the latter applying for a patent in Italy in October 1934, and obtaining one in the United States in 1940, for the basic process of producing radioactive isotopes by the use of slow neutrons (*2*). This pioneer patent has seven claims, one of which reads as follows:

"The process for the production of radioactive isotopes which comprises generating neutrons having a high average electron voltage slowing down and scattering said neutrons by projecting them through a screen of an element of the class consisting of hydrogen, helium, berylium, carbon, silicon and lead, which screen is of such thickness that the neutrons are slowed down to an average energy of not more than a few hundred electron volts, then passing said neutrons into a mass of an element of the groups having atomic numbers 11, 12, 13, 14, 17, 19, 23, 50, 64, 72, 74, 75, 77, 78, 79, and 92 and thereby producing from the latter element a radioactive isotope capable of emitting beta rays."

This patent had quite an interesting life and the stories connected with it make interesting reading (*3*). Suffice it to say, however, that it was impossible to build any type of reactor based on the use of slow neutrons without infringing Fermi.

This patent also bears evidence of the fact that Fermi and his associates were effecting the fission of U^{235} without fully realizing it at the time. In the course of describing the effect of bombarding uranium with slow neutrons they say:

"Chemical evidence seems to indicate that the carriers of the 13 and the 100 minute activities were not isotopes of any of the known heaviest elements, and that they were probably due to transuranic elements."

No basic patents were ever obtained on the fission process as such, although it is certainly conceivable that it would have been possible for some of the early researchers who were working on the idea at the time to do so.

A point of historical interest, not generally appreciated, is that, from the patent standpoint, Szilard actually preceded Fermi in the production of radioactive isotopes by the use of neutrons. He applied for a patent in Great Britain in March of 1934 and was granted one in the U. S. in 1939 for such a process (*4*). The first of nine claims reads as follows:

"The method of producing a radioactive element from a natural element by causing fast deuterons to impinge on a target containing lithium, and exposing a layer of the natural element to be transformed into a radioactive element to the neutron radiation emitted by the said target."

The part played by heavy water in the development of atomic energy is well known to most workers in the field, but relatively few are aware of the fact that a patent was applied for by Washburn for an electrolytic process for the manufacture of heavy water as early as 1933 (*5*).

One of the prime requisities of any invention to make it patentable is its "utility." In this connection the following interesting statement is found in the specification of this early heavy-water patent: "The full extent of the utility of this material is not known at the present time, but it has been recognized that by reason of its existence it is possible to make a large number of new and useful chemical compounds containing this new kind of hydrogen." Apparently the Patent Office found sufficient utility in the product, even at that time, to grant a patent on the process.

The same year (1939) that Szilard's basic U. S. patent issued and one year before the Fermi patent issued in the U. S., the work of Joliot's group in France resulted in an application being filed in the French patent office by Constantine Chilowsky for what appears to be the first patent in history covering a complete chain reaction (*6*).

The patent issued in France in 1941 amid loud cries of "shame" from members of the international nuclear fraternity who had been exchanging basic scientific information freely and considered the French action premature. A translation of the original French *résumé* reads as follows:

"The invention relates to heat generators utilizing the energy liberated by the atomic chain decomposition of a mass of uranium or compounds of uranium bombarded by an initial source of neutrons in the presence, on the one hand, of substances containing atoms of hydrogen and on the other hand, of substances containing atoms of cadmium or other compounds endowed with high absorbing power with respect to neutrons, independent of the temperature, the simultaneous presence of these two substances assuring the stabilization of the atomic decomposition."

This early French patent discloses many ideas and concepts basic to the reactor art as we know it today. These include the concept of "critical mass," the functions of "moderation" and "control," use of "lattice" and "reflector," including a "two region" arrangement, application of sodium and NaK for useful heat-transfer purposes and the use of cadmium and boron as "poisons." The patent discloses and claims an arrangement whereby fissionable material is finely dispersed in liquid lead and bismuth after the manner of a liquid-metal-fueled reactor.

A subsequent application by Chilowsky in the United States was rejected by the Patent Office principally on the ground that the applicant failed to disclose a device with sufficient definiteness so as to demonstrate its operability, another of the fundamental requirements of any patent. The Patent Office was reversed, however, by the Court of Customs and Patent Appeals (1956), which held, in effect, that the invention did not violate any of the known laws of atomic fission or other recognized scientific principles, that despite the newness of the atomic energy art the description was sufficiently definite to enable one skilled in the art to build such a device, and that the Patent Office tribunals failed to point out any specific feature which rendered the invention inoperable. In other words, the court held that the same standards of invention should be applied in the case of atomic-energy patents as in any others. The case was remanded to the Patent Office for further proceedings so that we have not heard our last from this patent application (*7*).

1940–1954

The advent of World War II with its Governmental control, security regula-

tions, and secrecy orders, drove the atomic energy art underground from where it has started to emerge only comparatively recently. Such a condition, of course, tends to hamstring the operation of any patent system.

Secrecy orders, whereby a patent whose publication would be detrimental to the national security must be withheld from issue upon order from the appropriate Government agency, have been a part of our patent law for some time. In the case of atomic energy, this has resulted in the withholding from issue of some patents for ten years or more, the date of issue thus bearing no relation to the date of development.

The next landmark patent is one for which Fermi applied in 1944, but which did not issue until 1957, covering a test exponential pile (*8*). This was the first U. S. patent to disclose a chain reaction, but it claims only the test pile of graphite and natural uranium, using a neutron source, and indium foils for measurement of neutron densities.

The real classic of U. S. reactor patents is that to Fermi and Szilard for a "neutronic reactor" that was applied for in 1944 and issued in 1955 (*9*). It is a real pioneer in the true sense of the word and, with its 35 pages and 42 figures, is a veritable treatise on reactor design. The patent treats of the chain fission reaction using slow neutrons and discloses various types of apparatus for effecting it. The concept of the multiplication constant k and of critical size are introduced. Use of the exponential pile is demonstrated. Properties of materials of reactor construction are discussed. Principles of control and xenon effect are illustrated. Sample calculations of important quantities are given and curves are plotted. The eight claims cover the general combination of natural uranium, uranium oxide with moderators of graphite and heavy water and include use of enriched uranium and other fissionable material in various geometries and combinations.

Another outstanding patent should be mentioned that is about as much of a classic as the one just discussed. It is concerned with a method and apparatus for the electromagnetic or electrostatic separation of isotopes using a "calutron." This was applied for by Lawrence in 1944 and issued in 1955 (*10*). With its 63 pages, 60 figures and 48 claims, it may be characterized also as a treatise on the subject.

Looking further at the reactor field we see issuing, comparatively recently, several interesting reactor patents that were applied for during the period from 1946 to 1952. All basic U. S. reactor patents that have issued to date have been Government owned.

Starting with the air-cooled reactor having a flattened activity curve of Young (*11*), we have, in order of filing, the original helium-cooled pile of Daniels (*12*), the heavy-water-moderated concept of Wigner (*13*), the graphite-moderated, helium-cooled arrangement of Wheeler (*14*) and the first light-water-moderated, enriched-uranium combination of Christy (*15*). These are followed, from the standpoint of application dates, by the swimming pool of Ohlinger (*16*), the improved heavy-water-moderated arrangement of Wigner (*17*) and the first U. S. patent disclosing and claiming a uranium and heavy-water slurry to Ohlinger (*18*). Reactor arrangements that produce superheated steam, a problem with which many reactor designers are currently concerned, are covered in patents to Metcalf (*19*) and Wigner (*20*).

Important techniques of basic radiation shielding are excellently summed up in four patents that claim the combination of concrete, paraffin and steel (*21*), cellulose and iron (*22*), dense concrete (*23*) and boral (*24*).

Designers of reactor-control systems should be familiar with the pioneer Fermi and Szilard divisional (*25*) and patents covering the basic control rod of Creutz (*26*), the projecting device of Goett (*27*) and the reflector-variation methods of Fermi (*28*) and Ohlinger (*29*).

A number of patents have issued on processes for the production of heavy water, one of the more interesting being Spevack's first U. S. patent, which is Government owned (*30*). A later, private, patent application for an improved process by Spevack encountered a secrecy order and later litigation with the AEC that is still going on (*31*).

The foregoing patents represent a collection of background reactor data in condensed form that should be very useful to all workers and indispensable to inventors in this field. It should be observed here that, up to the time of this writing, no basic U. S. reactor patents have issued covering such concepts as boiling-water reactors, intermediate and fast breeders, liquid-metal-fueled or organic-moderated reactors. Considering the length of time these have been under development, and that most of the related information has been declassified, issuance of patents in these areas appears somewhat overdue.

Whether or not the issuance of the early Chilowsky reactor patent in France would have resulted in a mad race to the patent offices of the world had it not coincided with the advent of World War II, will remain a moot question. The ensuing war, both hot and cold, denied to the nuclear industry the benefits of a normal patent system by forcing it behind its own iron curtain from where it has started to emerge only comparatively recently.

In the U. S. the biggest step taken to lift the curtain was the passage of the Atomic Energy Act of 1954. One of the stated purposes of that Act was ". . . to encourage wide-spread participation in the development and utilization of atomic energy for peaceful purposes . . ." and ". . . to encourage scientific and industrial progress." To our way of life this means the encouragement of an increased entry into the field by private industry supported by venture capital. In 1959 we hope to see further improvement in the situation when Congress decides whether or not to extend Sec. 153 of the present law, which calls for compulsory licencing.

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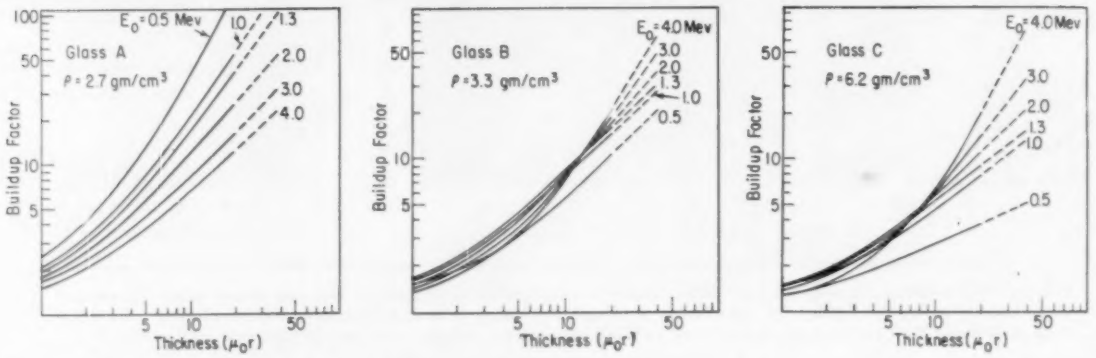

FIG. 1. Computed buildup factors for three glass compositions and six gamma-ray energies

Shielding-Glass Buildup Factors

By JOHN W. LINDNER,* *Pittsburgh Plate Glass Co., Pittsburgh, Pennsylvania*

Gamma-ray buildup factors for three shielding glasses are presented in the accompanying figures. The computations have been based on standard methods (*1–4*). These data enable the design of a shielding window giving the desired protection at a minimum cost. Previously it has been customary to correct for buildup by adding ~15% to the computed thickness. The data of Fig. 1–3 show that any rule of thumb like this is valid only for a single photon energy.

Computations. To compute buildup factors for a homogeneous mixture such as glass, it is only necessary to compute an effective atomic number for the glass (*1*). This can be done by (a) calculating the mean absorption coefficient per electron for the mixture and then (b) finding the element having the same absorption coefficient in the energy range over which Compton scattering is important.

The absorption coefficients of Fig. 2 were calculated from the data of Gladys White Grodstein (*5*). For energies of 0.1–2.0 Mev, the calculated absorption coefficients of the glasses of densities 2.7, 3.3, and 6.2 gm/cm³ agree to within ±3% with those of elements having atomic numbers 11, 54, and 73, respectively. The difference at 4 Mev is still less than 10%.

The dose buildup factors for the three glasses (Fig. 1) are plotted as a function of glass thickness expressed in relaxation lengths.

Glasses. The compositions of the glasses for which the computations were carried out are given in the table. Glasses A and B correspond to Pittsburgh Plate Glasses No. 6740 and No. 4966, respectively. Glasses of corresponding densities produced elsewhere can be considered identical for calculating buildup factors. Differences in composition do not have significant effect on effective atomic number. Glass C is an experimental glass that corresponds to commercially available 6.2-gm/cm³ glass.

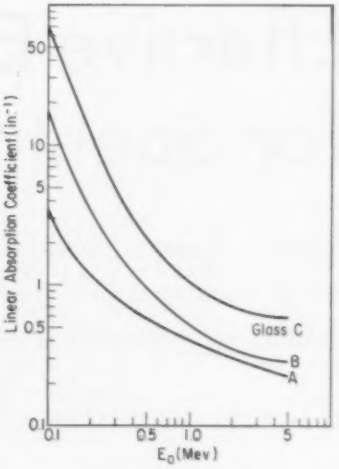

FIG. 2. Calculated coefficients

Accuracy. Goldstein and Wilkins claim an accuracy of ±5% for their calculations. After making allowance for probable errors in the choice of effective atomic numbers and graphical interpolation, the probable errors in the final results should be < ±15%. However, for shield thickness greater than 20 relaxation lengths, the error may be as great as ±20%.

* * *

The author wishes to express his gratitude to Mr. Carlo Del Carlo, who prepared the curves.

Compositions (wt%) of Three Shielding Glasses

Glass	Density (gm/cm³)	SiO_2	PbO	B_2O_3	Na_2O	BaO	K_2O	CeO_2
A	2.7	64.8	—	3.0	6.5	15	9.0	1.7
B	3.3	49	34.8	—	0.5	—	14	1.7
C	6.2	5.5	82	12.5	—	—	—	—

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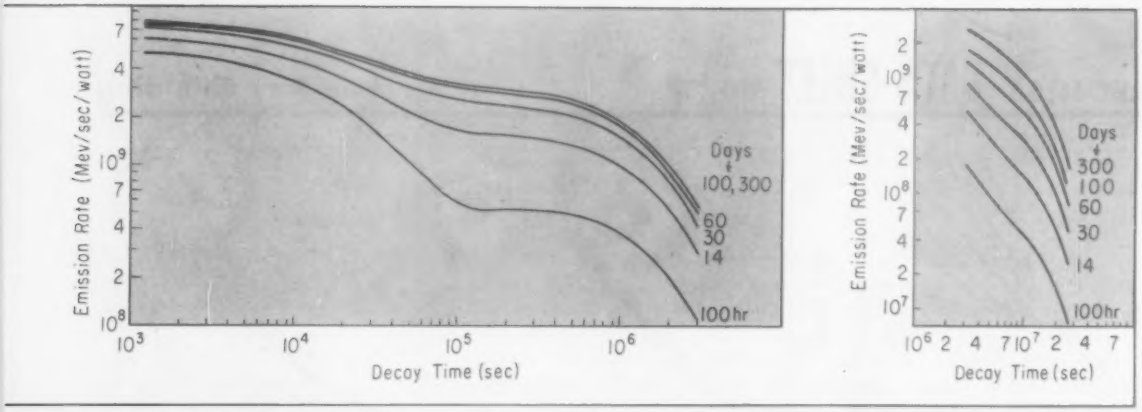

FIG. 1. Photon-emission power from U^{235} fission products as a function of irradiation time and decay time. Curves are computed for nuclides of Table 1 for decay times of 20 min to 35 days (left) and 35 days to 300 days (right). Contributions of Zr^{95} and Nb^{95} (which become significant at longer delays) are included in curves on right here and in Figs. 2–5

Effective-Energy Method for Spent-Fuel Shielding

Suitable graphs permit substitution of a single photon energy for a fission-product spectrum. Shielding problems reduce to finding the penetration of photons of this energy

By RAMON L. ASHLEY, *Atomics International, Canoga Park, California*

A SIMPLE METHOD makes it possible to compute the effectiveness of spent-fuel shields with fair accuracy and a minimum of effort. It consists in finding an effective photon energy that can be used in place of the spectrum from the spent fuel.

To find the radiation level at the surface of a given shield by this method:

1. From curves prepared for the purpose, obtain the gamma-ray emission rate of the source for the irradiation and decay times under consideration.
2. From another set of curves find the effective photon energy of the source for a given shield thickness.
3. Use the linear absorption coefficient, flux-to-dose conversion factor and buildup factor for the effective energy to perform the shielding computation.

To determine shielding for a given source, one must consider different thicknesses, iterating steps 2 and 3.

The method has been applied to shielding of spent U^{235} fuels with four different shielding materials. Comparison with one set of experimental data indicates that the results are accurate for cooling times >45 min, for irradiation times as short as 100 hr. Unidentified short-lived nuclides among the fission products make it inapplicable for shorter cooling times. For still longer irradiations, increased accuracy for shorter cooling times is expected. Neglect of low-energy γ-rays limits application to "thick" shields.

Choice of Gammas

Shielding requirements for spent fuel are determined by the most energetic fission-product gamma rays. Softer radiations, even in greater quantity, are more easily stopped because of the rapid increase in the absorption coefficient with decreasing photon energy.

Since, in practice, shields required for spent fuel are thick shields, thin shields are not considered in this analysis. It is specifically intended that this method be applied to thick, single-region shields, i.e., only for more than 6 in. of lead, 6 ft of water, 3 ft of ordinary concrete and 2 ft of heavy concrete.

The fission products used for the computations are mostly those emitting gamma photons with energies ≥ 1.60 Mev (hereafter called hard gamma rays). This is a convenient cutoff point because the 1.60-Mev La^{140} gamma is frequently the controlling factor in spent-fuel-shield design. Zr^{95} and Nb^{95}, with lower-energy gamma photons, have been included because, in the thinner shields analyzed, their high fission yields and long half-life make them important.

Table 1 lists the relevant characteristics of the isotopes. The comments indicate the assumptions that were made for the purposes of computation.

Calculations

Determining the energy output of hard fission-product gamma rays is straightforward. The energy output of each of the gamma rays listed in Table 1 is determined from the following expression

$$P_i = g_i E_i F \left\{ \frac{Y_i \lambda_i \lambda_{i-1}}{\lambda_i - \lambda_{i-1}} \left[\left(\frac{1 - e^{-\lambda_{i-1}\tau}}{\lambda_{i-1}} \right) e^{-\lambda_{i-1} t} - \left(\frac{1 - e^{-\lambda_i \tau}}{\lambda_i} \right) e^{-\lambda_i t} \right] \right\}$$

The symbols are

- P_i = energy output from the ith gamma ray (Mev/sec/watt)
- g_i = number of photons of energy E_i emitted per disintegration
- E_i = photon energy (Mev)
- Y_i = fission yield of the nuclide chain
- F = fission rate per watt = 3.1×10^{10} fissions/sec/watt
- λ_i = nuclide decay constant (sec^{-1})
- λ_{i-1} = decay constant of the parent nuclide (sec^{-1})
- τ = irradiation time (sec)
- t = decay time (sec)

The total energy-emission rate from all of the listed gamma rays is simply the sum of all individual contributions. This sum is shown in Fig. 1 for various irradiation and decay times.

Effective energy. The effective energy of this radiation is defined as the photon energy that will suffer the same attenuation as the actual spectrum when confronted by a given shield. This is computed by finding the attenuation of each of the listed gamma rays. The shielded dose rate from each gamma ray is

$$D_i(s) = D_i(u)[(B_r)_i e^{-\mu_i x}]$$

Here the symbols are

- $D_i(s)$ = shielded dose rate from the ith gamma ray (r/hr/watt)
- $D_i(u)$ = unshielded dose rate from ith γ-ray (r/hr/watt)
- $(B_r)_i$ = dose buildup factor for the shield geometry
- μ_i = linear absorption coefficient of shield for γ-ray (cm^{-1})
- x = shield thickness (cm)

The unshielded dose rate $D_i(u)$ is evaluated by using a factor to convert photon flux to dose rate (*1*). The actual attenuation of the spectrum G can be computed as the ratio of the total shielded and unshielded dose rates

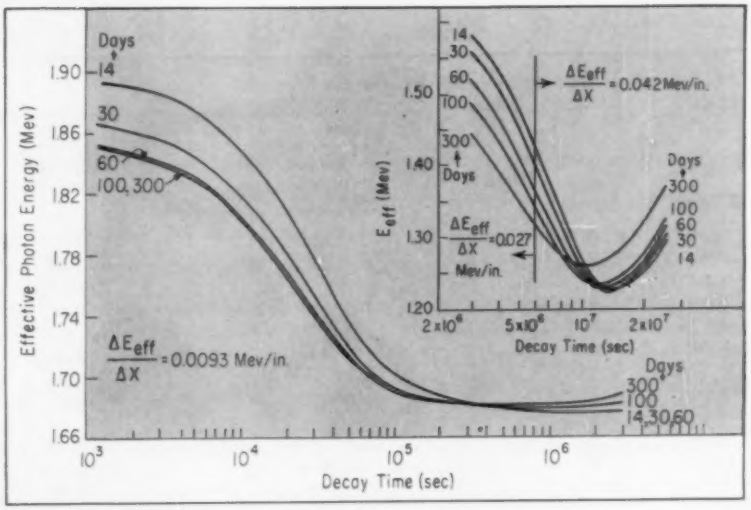

FIG. 2. Effective photon energy for 8-in. lead shield

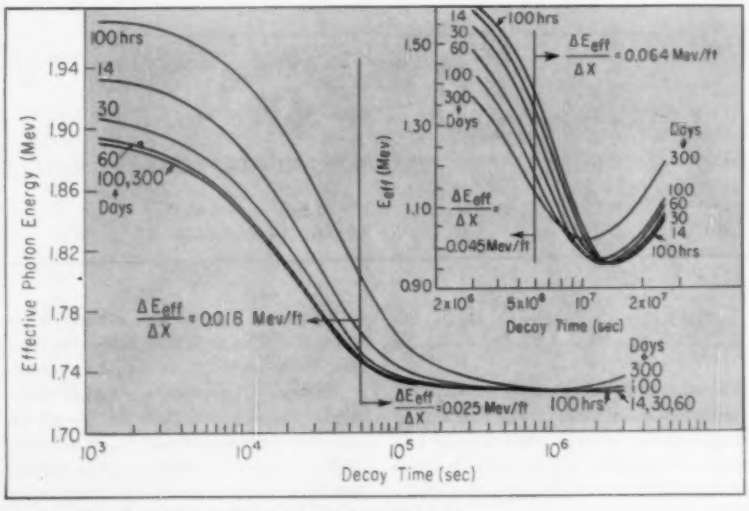

FIG. 3. Effective photon energy for 8-ft water shield

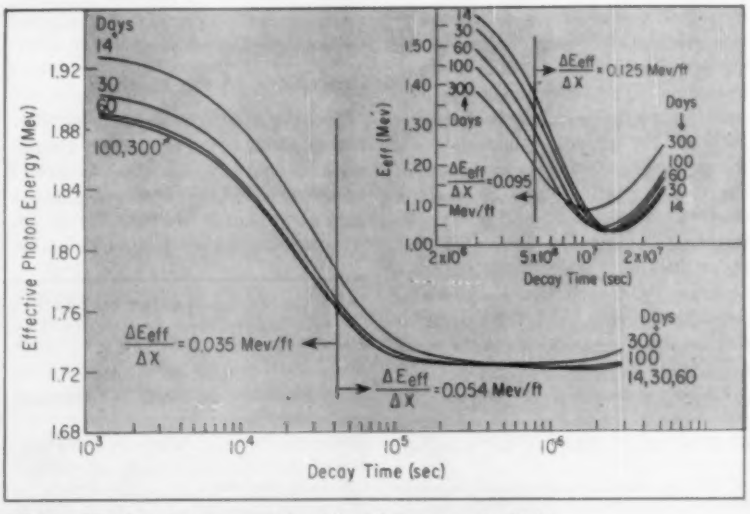

FIG. 4. Effective photon energy for 4-ft ordinary concrete shield

TABLE 1—Hard-Gamma-Ray-Emitting Fission Products

Nuclide	*Gamma-ray energy (Mev)*	*Gamma rays emitted per disintegration (%)*	*Portion of decay chain determining time dependence after shutdown*	*Fission yield (11) (%)*	*Comments*
Br^{84}	1.89	35	$Se^{84}(2m) \rightarrow Br^{84}(32m)$	0.65	Decay scheme inferred from *10*. It is the same as used in *11*
Kr^{87}	1.89	12.5	$Br^{87}(56s) \rightarrow Kr^{87}(78m)$	2.0	Assumed branching ratio based on decay scheme of *10*
	2.3	12.5			
Kr^{88}	1.8	12	$Br^{88}(16s) \rightarrow Kr^{88}(2.77h)$	3.1	Gamma-ray intensities inferred from data in *10*
	2.18	68			
Rb^{88}	1.86	20	$Kr^{88}(2.77h) \rightarrow Rb^{88}(17.8m)$	3.1	Absolute intensities inferred from relative-intensity measurements noted in *10*
	2.8	2.0			
Rh^{106}	2.4	0.25	$Ru^{106}(1.0y) \rightarrow Rh^{106}(30s)$	0.52	Line intensity inferred from data in *10*
Sn^{125}	1.9	5.0	$Sn^{125}(9.4d) \rightarrow$	0.028	Line intensity inferred from data in *10*
I^{132}	2.0	2.7	$Te^{132}(77.7h) \rightarrow I^{132}(2.4h)$	4.4	Intensity of 2.0 Mev line taken from *12*
I^{134}	2.2	1.0	$Te^{134}(44m) \rightarrow I^{134}(52.5m)$	5.7	Intensity of 2.2-Mev line uncertain. Assumed to be as in *11*
I^{135}	1.8	73	$Te^{135}(2m) \rightarrow I^{135}(6.68h)$	5.9	Decay scheme inferred from data in *10*. 2.4-Mev intensity agrees with *11*
	2.4	2.0			
La^{140}	1.6	95	$Ba^{140}(12.8d) \rightarrow La^{140}(40h)$	6.17	Absolute intensities of 1.6- and 2.5-Mev lines inferred from data in *10*. Intensity of 2.9-Mev line taken directly from *10*
	2.5	4.9			
	2.9	0.10			
Pr^{144}	2.18	0.73	$Ce^{144}(275d) \rightarrow Pr^{144}(17.5m)$	4.64	Intensity of 2.18-Mev line inferred by assuming 0.86-Mev beta in 1% of decays
Eu^{156}	2.0	60	$Sm^{156}(10h) \rightarrow Eu^{156}(15.4d)$	0.013	Intensity of 2.0-Mev line inferred from data in *10*. It is same as used in *11*
Zr^{95}	0.721	99	$Y^{95}(10.5m) \rightarrow Zr^{95}(65d)$	6.0	Decay scheme taken directly from *10*
Nb^{95}	0.745	100	$Zr^{95}(65d) \rightarrow Nb^{95}(35d)$	6.0	Decay scheme taken directly from *10*

$$G(\tau,t,x) = \sum_i D_i(s) \Big/ \sum_i D_i(u)$$

From curves of attenuation ($B_r e^{-\mu x}$) against photon energy, one can find a single photon energy that suffers the same attenuation as the entire spectrum. This is designated as the effective energy of the spectrum.

Computations. Table 2 lists the characteristics of 16 shields treated by this method (*2*)* and indicates the sources of information used in the computations. The effective-energy results for an intermediate thickness of each of the shielding materials are shown in Figs. 2–5. Separate sets of curves are given for two intervals of decay time (see caption, Fig. 1). In the region of overlap the curves that cover the longer decay times are more accurate. On each figure are coefficients that permit using the graphs for thicker and thinner shields of the same materials.

Linear absorption coefficients for magnetite concrete were not available, so they were evaluated by standard techniques. The results are given in Table 3. The available linear absorption coefficients (*3*) included coherent scattering. However, since this scattering phenomenon does not result in any loss of energy and only a very slight change in direction, its contribution was omitted from the total cross sections, as should be done in shielding work. Buildup factors for ordinary and magnetite concretes were evaluated by the equivalent-*Z* method (*4*).

Limitations of the Method

Since the contribution from low-energy gamma rays is omitted, attenuation in thin shields cannot be determined. Actually the effective-energy data as presented can probably be extrapolated and used for rough evaluations of shields that are somewhat thinner than those for which the computations were made. Accuracy well within a factor of ten should be possible for thicknesses down to 4 in. of lead, 4 ft of water, 2 ft of ordinary concrete and 1.25 ft of magnetite concrete.

As indicated in Table 1, most of the decay schemes are either assumed or inferred, and more experiments may show that these schemes need modification. For example, recent experimental information (*6*) indicates a decay scheme for I^{135} that is much more complex than the one used in this analysis. The adequacy of the decay schemes used will be revealed by more detailed experiments or comparison of the predictions of this method with spent-fuel-shielding studies.

TABLE 2—Shields Treated by Effective-Energy Method

Material	*Thicknesses*	*Assumed density (gm/cm³)*	*Ref. for compos., buildup and absorption coefficients*
Lead	6–12 in.	11.3	(*3*, *4*)
Water	6–12 ft	1.0	(*3*, *4*)
Ordinary concrete	3–6 ft	2.32	(*3*)
Magnetite concrete	2–4.25 ft	3.7	(*3*, *5*, see Table 3)

* The reference includes sample computations and explanations suitable for use by engineers not trained in shielding.

The fission yields in Table 1 are those for U^{235}. However, the change in the yield curves from one fissionable nuclide to another is fairly small (7). If the yield of a given nuclide changes by a factor of two, the resultant dose rate from this nuclide changes by a factor of two, but the total dose rate from the source is affected to a lesser degree. Therefore the application of these figures to U^{233} and Pu^{239} should give adequate results for preliminary analyses.

Uncertainties in buildup factors for thick, multiregion shields limit the application of this method to single-region or monolithic shields. Some work on buildup in thin two-medium shields has been reported recently (*8, 9*), but whether the formulation applies to deep penetrations has not been determined. A more specialized method must be used for a shield that has two or more layers of widely different atomic numbers and has attenuations in each region that are comparable. On the other hand, if most of the attenuation is in one of the materials, the buildup will be adequately accounted for by assuming that all of the penetration is in that material. If the atomic numbers are reasonably close, as with aluminum and ordinary concrete or iron and magnetite concrete, it is accurate to assume a buildup corresponding to a single shield of one of the materials. The assumption can even be extended to an iron-water shield.

Comparison with Experiment

Only one set of accurate experimental information is available for comparison so far. This is a series of measurements (*13*) in the water around the Oak Ridge Bulk Shielding Reactor after a 100-hr run at 100 kw. None of the fuel elements had operated at significant power levels before the experiment. Table 4 is a comparison of the measurements and computations by this method. From Table 4 it is apparent that the method is adequate for cooling times longer than ~45 min. There appear to be unidentified short-lived hard-gamma emitters among the fission products that increase the dose at short cooling times.

It is not surprising that the nuclides of Table 1 are not adequate to represent the hard-gamma dose for short cooling times, at least for short exposures. Many attempts to calculate the gamma-ray energy after a burst by summing individual emitters have resulted in decided departures from the Way-Wigner empirical formula: $1.26t^{-1.2}$ Mev/sec/fission. Such sums are always too low at short cooling times, the departure occurring at ~60 min. For 20 min after the burst, calculations are low by at least a factor of two. The indication is that some important short-lived gamma-ray-emitting fission products are omitted. It can be inferred, however, that for long irradiations the contribution at short cooling times from the unidentified emitters will become less important, so that the method would yield better results.

For decay times greater than 45 min, the ratio of calculated to measured values is fairly constant. This indicates that the source spectra chosen for the analysis are adequate for evaluation of shielding requirements for cooling times longer than 45 min.

TABLE 3—Absorption Coefficient for Magnetite Concrete

E_γ (*Mev*)	μ/ρ (cm^2/gm)
0.70	0.0733
0.80	0.0678
0.90	0.0638
1.00	0.0600
1.20	0.0551
1.40	0.0513
1.60	0.0480
1.80	0.0453
2.00	0.0430

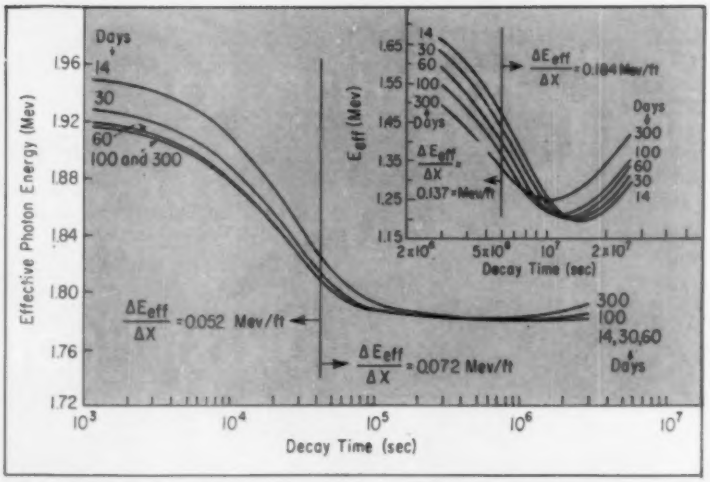

FIG. 5. Effective photon energy for 3.5-ft magnetite concrete shield

TABLE 4—After-Shutdown Dose Rates from BSR

Decay time (*min*)	*Water-shield thickness* (*ft*)	*Dose rate* (*mrem/hr*)	
		Calculated	*Measured*
20	8	35.2	80.3
30	8	33.2	64
45	8	31.6	53
60	8	30.4	43.5
120	8	25.9	30.5
240	8	15.1	20.5
120	6	471	540

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Designing for Blast Protection

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DESIGNING for blast protection in a reactor is largely a matter of understanding the properties of the strong shock waves that would emanate from hypothetical nuclear explosions. The concept behind the blast shield, for instance, is that a shock wave will dissipate a large part of its energy in traveling through "crushable" material. The use of air spaces to channel explosions depends on the great preference that hydrodynamic energy has for flowing in rarefied media. A consideration of shock-wave properties also leads to the conclusion that lengthening the duration of energy release, isolating structures by air gaps and using reflecting barriers will usually be disappointing as techniques for containment.

Shock Wave Concepts

The typical characteristics of a shock wave formed by the abrupt release of energy are sketched in Figure 1. Although the pressure pulse may start out with a more gradual rise, as it travels it will quickly "shock up" to take on the form shown in Fig. 1. This steepening of the front depends on two simple and homely properties of matter: that volume decreases under pressure and that resistance to compression increases as pressure is increased. Other hydrodynamic variables—material velocity, sound velocity and transport velocity—behave similarly to the pressure variation.

As depicted in Fig. 1, when the shock front passes through a unit mass of material it compresses it from volume V_0 to V_s. During this time the unit mass absorbs a total energy of $P_s(V_0 - V_s)$ (the area of the rectangle in Fig. 2), where P_s is the peak pressure of the shock. Part of this energy $[\frac{1}{2}(P_s - P_0)(V_0 - V_s)]$ appears as kinetic energy of the mass, corresponding to the area of the triangle in Fig. 2. The remainder $[\frac{1}{2}(P_s + P_0)(V_0 - V_s)]$ is in the form of internal energy, corresponding to the rest of the rectangle. For all pressures $P_s \gg P_0$, the kinetic and internal energies are nearly equally partitioned.

The table provides a comparison for the energy per unit volume for several different materials at several different pressure levels. The outstanding result is the very small amount of energy needed in solid and liquid media to produce very strong pressure pulses. The pressure of 100 atm is especially interesting because it represents roughly the pressure in the fireball from an atomic bomb in air about the time of breakaway; the associated energy density is obviously sufficient to raise the air temperature by several thousands of degrees. The same pressure in water, concrete or steel is produced by very much smaller amounts of energy, corresponding to a temperature rise of a

Shock-Wave Energy Density

	Energy density (cal/cm³)*			
Pressure (atm) =	10	100	1,000	10,000
Air	0.72	15.5	240	1,910
Water	1.4×10^{-4}	1.4×10^{-3}	1.4	53
Concrete	5.5×10^{-5}	5.5×10^{-4}	5.5×10^{-3}	5.5
Steel	1.2×10^{-5}	1.2×10^{-4}	1.2×10^{-3}	1.2

* Based on $E_i = \frac{P}{41.8}(V_0/V - 1)$ cal/cm³.

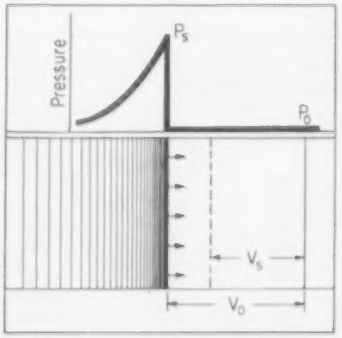

FIG. 1. Variation of pressure across shock front

tiny fraction of a degree. Thus, a little energy literally goes a long way in producing shock waves in solids and liquids.

In solids or liquids the pressure decays from a peak value at the shock front to values near zero at the origin of the explosion. The interior is better thought of as a vacuum than as a high-pressure zone that drives the shock ahead of it. In gases the pressure levels off on the interior to a value that is approximately one-third the peak pressure at the shock front. For gaseous explosions, the peak pressure at the shock front may be estimated roughly and reliably by distributing the energy over the volume of the explosion with a factor of two or three for the pressure at the shock front.

Figure 2 shows the thermodynamic pressure-volume history for a unit mass of material in the path of the shock. The shock front first compresses the material along (for practical purposes) the straight-line path *afc* to a point on the Rankine-Hugoniot curve* (*abc*).

If a material is shocked to a temperature sufficient to vaporize it, after the shock has passed it will expand along an adiabat and reach a final specific volume corresponding to a gas thousands of times larger than can be shown on the present scale. For shock pressures below the vaporization level, the material will also expand to ambient pressure along an adiabat (*cde*) but will reach a final specific volume substantially the same as its original specific volume V_0; the difference will be of the order of the difference in volume between water at 99° C and 0° C. In general, one can show that locally the slope of the adiabat lies between the Rankine-Hugoniot curve and the straight line joining the end points. Since the slope of the adiabat is so bounded and for a solid or liquid must terminate near P_0V_0, it follows that the adiabats for solids and liquids are, for all practical purposes, nearly identical with the Rankine-Hugoniot curve itself. The area under the adiabat is that part of the internal energy that is returned to the shock when the material expands and is called "useful hydrodynamic energy." The remainder of the internal energy (the lens-shaped area in Fig. 2) is retained by the material as "waste heat" and appears as a temperature rise in the material.

* The Rankine-Hugoniot equations are relationships among pressure, density, shock velocity, material velocity and other hydrodynamic variables across a shock front as obtained by applying conservation of mass, momentum and energy.

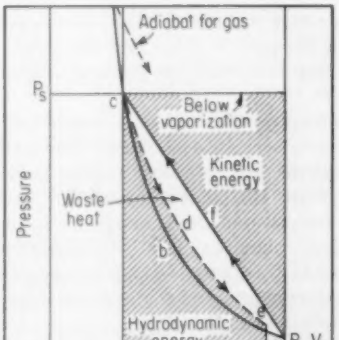

FIG. 2. Relation of pressure and volume in material traversed by shock wave

The strategy of blast shield design is to use materials characterized by a high waste-heat energy and a low hydrodynamic energy so that the energy of the shock wave is soaked up as quickly as possible. Thus the ideal shock-wave absorbers are materials that crush down to small volumes at relatively low pressures. In such cases, the Rankine-Hugoniot curve is much more bowed than shown in Fig. 2. Nearly all the internal energy appears as waste heat and little if any appears as useful hydrodynamic energy. (The kinetic-energy fraction, however, is still transferred to the next particle through the conservation of momentum.) Energy is also converted to waste heat by more complicated processes: heat transfer between phases, slippage along crystal boundaries, phase changes, etc. These effects cause the expansion curve to terminate further from V_0 (closer to V_s) and contribute further to the absorption of internal energy behind the shock in a good absorber.

If Q is the waste heat per unit volume, the useful thermodynamic energy remaining in a spherical shock wave at distance R is

$$E_s = W - 4\pi \int_0^R Q(P) R^2 \, dR$$

where W is the total energy of the explosion.

Figure 3 shows the qualitative behavior of the ratio E_s/W as a function of distance typical for most materials. Near the end of the material vaporization region, the energy-content ratio

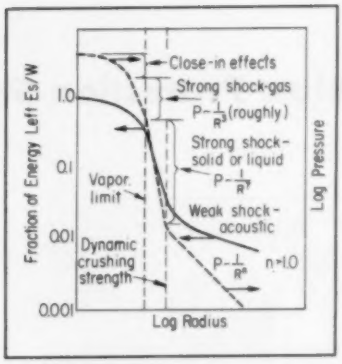

FIG. 3. Pressure and energy content of spherical shock wave as function of distance from origin

is down to about 0.5 for most materials. In the region of pressures below the vaporization level and above the crushing strength of the material, the useful-energy fraction falls very rapidly down to a few per cent of the original energy in the shock.

The peak pressure versus distance curve (Fig. 3) shows the same qualitative behavior as the energy-content curve. Close in the pressure decay may be slow due to mass effects, radiative effects or heterogeneity at the source. Beyond the close-in effects, there follows a range of pressures in which the shock wave is sufficient to vaporize the material behind it. During this phase the peak pressure decays roughly as $1/R^3$ but only roughly so. Below the pressure sufficient to cause vaporization the absorption of energy through the waste-heat process is very rapid. For good absorbers the pressure decay is as high as $1/R^7$ or $1/R^9$. This rapid decay in pressure continues until it falls to the dynamic crushing strength of the material. At this pressure the waste-heat mechanism becomes small, the wave becomes elastic, and pressure decays roughly as $1/R$.

Figure 3 shows the advantage of capitalizing on the properties of the material between its vaporization pressure and its crushing strength. There is a widespread tendency in the current literature to describe shocks on the basis of a similar assumption which requires the pressure to decay like $1/R^3$ close in and, on the basis of the acoustic approximation, to decay as $1/R$ far out. However, as the figure shows, the cubic decay close in is only an asymptotic limit for ideal gases, i.e., nonabsorbing ones. The same remark applies to the acoustic approximation at large distances; conservation of energy requires that $n > 1$. (*Cont.*)

Blast Protection Strategy—These Ideas Work . . .

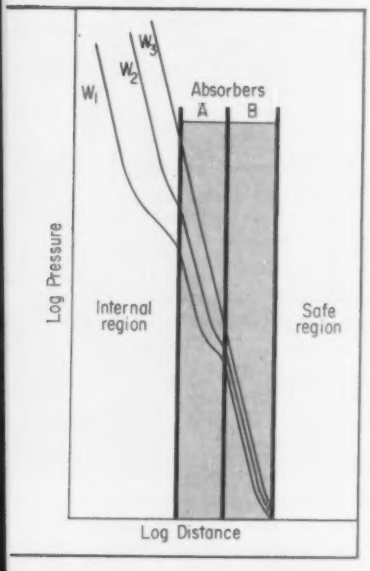

FIG. a. Pressure vs. distance pattern in blast shield for three different initial energy releases

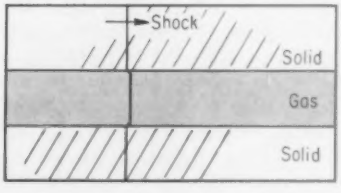

FIG. b. Shock wave in air channel

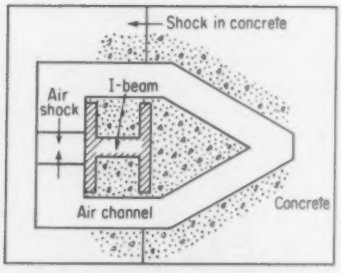

FIG. c. Air-channel arrangement to preload I-beam against shock wave

Blast Shields

From the text it follows that the ideal blast shield will consist of layers of absorbing materials with successively lower crushing strengths chosen to match the pressure-distance curve so as to convert as much energy as possible into waste heat in the shortest distance.

Consider a pressure-distance curve (see Figure *a*) from an explosion with energy W_2. Close to the source, the reactor material itself may be an adequate absorber; for example, water is an excellent absorber down to pressures of 20,000 atm. At some pressure level, too low to provide further absorption by the reactor material, or wherever the protection of the reactor requires, a weaker and more absorbing layer is introduced. The thickness of the layer is limited by the partition between internal and kinetic energy, the energy in the explosion and the pressure level at which absorber A reaches its crushing strength and ceases to be efficient for absorption. Steel plates are interposed between layers to prevent a breakthrough of energy by the channeling mechanism (see below), to flatten out the shock front and to make the shock act more like a smooth piston on a subsequent layer. Absorber B is a still weaker material than A, designed to be suitable for absorption at the pressure levels expected there.

The question is sometimes raised whether a blast shield designed for a maximum expected pressure will defeat the purpose of a smaller but much more likely explosion. The graph shows the comparison for both larger and smaller explosions. Familiar blast-scaling concepts apply, so that on these logarithmic coordinates the pressure-distance curves are more or less displaced horizontally within a given region. For a smaller explosion, W_1, the crushing pressure of the internal region would be reached at a shorter distance and more of the internal material would be an efficient transmitter of shocks. The same remark applies in the regions of absorber A and absorber B. The final pressure would be much closer to the pressure from explosive W_2, but always below it. For a very strong explosion, such as W_3, the pressure may be high enough so that all three regions are excellent absorbers.

Strictly speaking, an optimum shield can be tailor-made to any given situation. But any given shield, as long as it does not all vaporize, will be more efficient at higher energies than at lower energies. It will be less efficient for smaller explosions, but the shield will always reduce the pressures to some safe level beyond the blast shields. In this sense the blast shield constitutes a pressure gate with a pressure level equal to the value designed at the outer side of the protective blast shield.

Channeling

When a shock travels along a solid-gas interface (see Fig. *b*), there is a marked tendency for the shock energy to spill from the solid material into the gaseous region. This phenomenon is called channeling and is used as a means of blast protection alternative to the blast shield.

The physical reason for channeling comes from the hydrodynamic requirement that the peak pressure of the shock be continuous across the interface. The table on p. 82 shows that to satisfy this condition the specific energy content of the gaseous region has to be thousands of times greater than that of the solid or liquid material. In designing for blast protection the essential idea is to use channeling to distribute the energy as rapidly as possible over large volumes. The geometry of most reactors provides ample opportunities to distribute the shock energy over large volumes, to direct it away from critical structures and to distribute it uniformly and quickly into the final outer containment shell.

Figure *c* dramatizes what can be done by channeling if the need exists. By a proper geometrical arrangement and a consideration of shock velocities, it would be possible to trick the shock into loading the beam on the far side first. In reality, such a panacea could not be easily achieved; the scheme would probably be defeated by spalling and its usefulness limited only to clipping of the initial pressure peaks.

These Ideas Don't Work . . .

Energy-Release Duration

The idea of slowing down the nuclear or chemical reaction that produces the explosion is often tacitly assumed to be a method of containment or at least an argument that the design based on a rapid explosion is conservative. Figure *d*, which shows the effect of energy-pulse duration on the pressure at a distant wall, illustrates the pitfalls in such an argument. Since it is fairly well accepted that nuclear explosions are "less efficient" than TNT explosions, the curve must rise in the regions of very short durations. To be sure, for some long enough duration of energy release, the pressure at the wall can be reduced to acceptably safe levels. Unfortunately, a maximum must exist in between. The table (p. 82) showed how very small amounts of energy were required to produce very sizable pressure pulses. It turns out that the duration of energy release required to get far enough beyond the maximum to ensure that the pressure stays below safe limits turns out to be of the order of tens of seconds.

Figure *e* shows another comparison of pressure-distance curves for fast and slow energy releases. Close to a source of fast energy release, the pressures are high and energy is wasted rapidly. A slower release will keep the pressures lower near the source, but the dissipation will not be as fast; more energy will be available, and eventually the curves will cross. A very slow energy release would dissipate practically none of the energy close in. Quantitatively, there may be as much as 100 times more hydrodynamic energy in the shock at a long distance from a slow explosion than from a fast one. One can make the seemingly paradoxical statement that, far enough out, the pressures will always be higher from a given energy release of slow duration than from the same energy released over a shorter period. The damage from a fast energy release may be more spectacular close in, but the acceptably safe pressure levels may occur far out, after the curves cross.

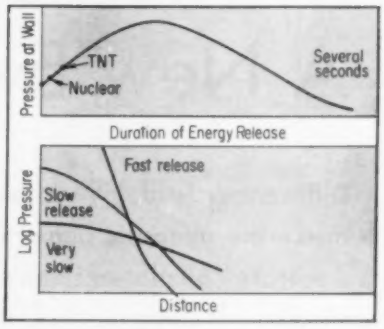

FIG. d. (top) Pressure at distant wall from spherical blast as function of duration of energy release. Total energy released is held constant
FIG. e. (bottom) Pressure very far from blast origin for three different rates of release of same total energy

Isolation Air Gaps

It is true that the pressure behind a shock drops very rapidly in passing from a solid to a gaseous phase (see Fig. *f*). This drop is roughly of the order of the density ratio across the interface. Thus when the shock passes into the air it is much reduced in size and in addition a rarefaction almost equal in size to the original shock begins to travel back through the solid medium. However, when the transmitted shock reaches the other wall, it is reflected by a factor of at least two, perhaps as high as twelve. This reflected shock meets the original interface and is reflected again. A series of multiple reflections continues—and the hydrodynamics require that they continue—until the air density in the gap is raised to densities comparable to the solid itself. Despite the first spectacular drop in pressure at a solid-to-air interface, the final pressure in the air gap is raised practically to the level originally existing in the solid.

The pressure wave may not be as flat as shown here and positive gains may be made if the gap thickness is comparable to the region of increased pressure behind the shock. Despite the enormous pressure drop across the boundary, however, a gross consideration of conservation of energy will also require the duration of the transmitted wave in air to be correspondingly long. In most cases, spalling from the near interface as well as multiple reflections within the gap will deny the possibility of isolation as a means of reducing shock pressures.

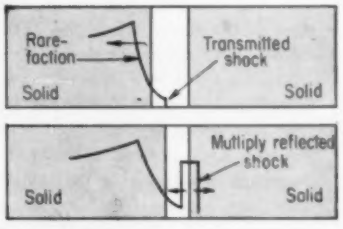

FIG. f. Progress of shock wave through air gap

Reflecting Barriers

Figure *g* illustrates the deficiency of another scheme that attempts to use shaped barriers to "break up the shock." The dilemma is that a pressure enhancement occurs from reflections when the shock meets such an obstacle. This pressure enhancement may be aggravated by multiple shocks and by shock intersections as illustrated in the figure. By the time the shock reaches the narrow neck shown at the top, the pressure loading due to high pressures within the neck would be nearly equivalent to the loading caused by original pressure distributed over the entire area. The latter statement becomes truer the more rigid and incompressible the barriers become (i.e., less absorptive).

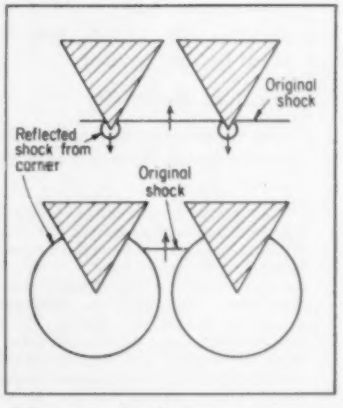

FIG. g. Shock reflections from barriers

Reactor Kinetic Functions: A New Evaluation

Differences in delayed neutron characteristics of the several fuel nuclides make the dynamic behavior of reactors dependent on the fuel used. Accurate calculations show these differences in reactor kinetics

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TWO FUNDAMENTAL reactor kinetic functions, the period-vs.-reactivity relation and the zero-power transfer function, are determined almost exclusively by the delayed-neutron characteristics. Moreover, since the total delayed-neutron fraction and the relative abundance and half-lives of the six delayed groups differ somewhat for the various fissionable nuclides, the kinetic functions will depend upon what combination of fissionable materials is in the core. Using the very latest delayed-neutron data we have calculated in detail the two reactor kinetic functions for six fissionable nuclides: U^{233}, U^{235}, U^{238}, Pu^{239}, Pu^{240} and Th^{232} (see Fig. 1). Interpolation of the functions obtained for these limiting "pure-isotope" cases will allow estimates for the kinetic behavior of "mixed-isotope" systems.

Period vs. Reactivity

The transient equations* relating the neutron density and concentration of delayed-neutron precursors in an assembly can be written

$$\frac{dn}{dt} = \frac{K_p - 1}{l} n + \sum_i \lambda_i \gamma_i c_i$$
$$\frac{dc_i}{dt} = \frac{\beta_i K}{l} n - \lambda_i c_i \qquad (1)$$

In these equations

n = neutron density
K = neutron reproduction number for finite geometry
$K_p = K(1 - \gamma_{avg}\beta)$ = prompt-neutron reproduction number for finite geometry
l = prompt-neutron lifetime (or "cycle time") for finite geometry
λ_i = decay constant (reciprocal mean life τ_i^{-1}) of the ith delayed neutron group
c_i = density of ith delayed-neutron-group precursor
β_i = ith group fraction of total neutrons from fission
$\beta = \sum_i \beta_i$ = total delayed neutron fraction
γ_i = effectiveness (in producing fission) of ith group delayed neutrons compared with prompt neutrons
$\gamma_{avg} \equiv \beta^{-1} \sum_i \gamma_i \beta_i$ = average delayed neutron effectiveness.

For constant K_p (e.g., following a step change in reactivity), the space and time variables in Eq. 1 are separable. The resulting solution of Eq. 1 is

$$n = \sum_j A_j e^{\omega_j t} \qquad (2)$$

where the A_j are determined by the initial power level of the assembly and ω_j are the roots of the characteristic equation

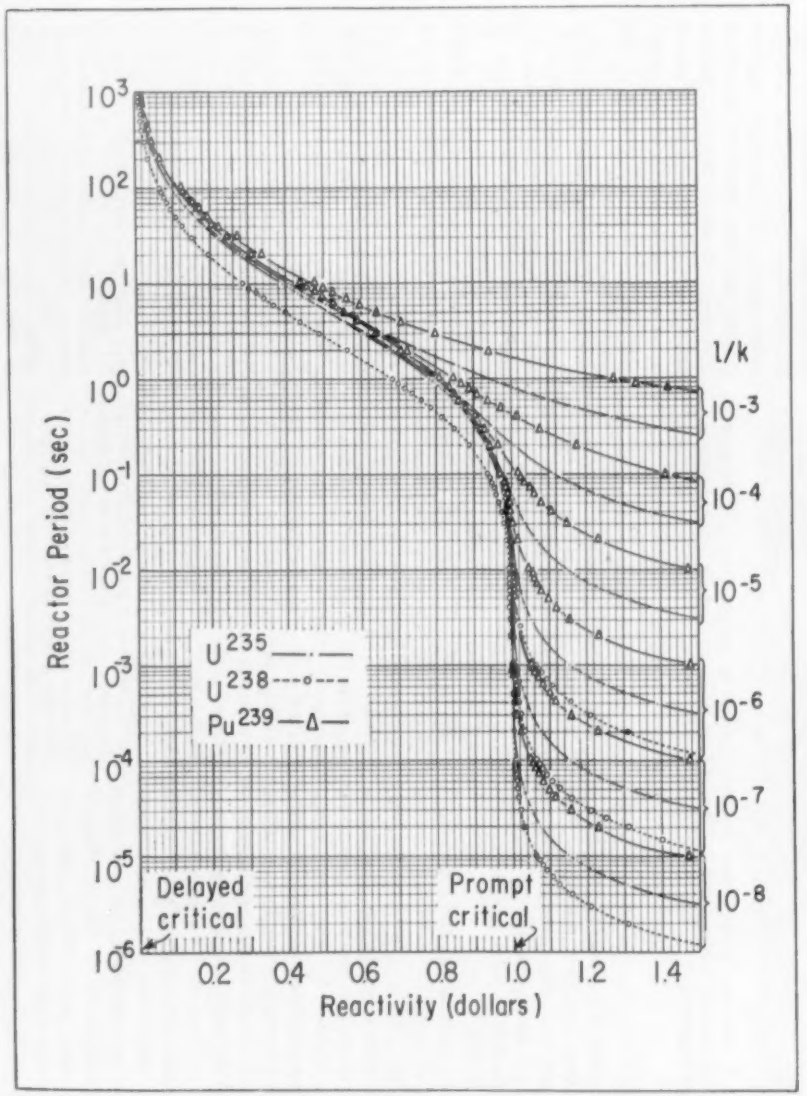
$$\omega_j = \frac{K_p - 1}{l} + \frac{K}{l} \sum_{i=1}^{6} \frac{\gamma_i \beta_i \lambda_i}{\omega_j + \lambda_i} \qquad (3)$$

If we replace the ω_j by their corresponding periods, $T_j \equiv \omega_j^{-1}$ and express reactivity in units of $\Delta K / K \gamma_{avg} \beta$ (the dollar), Eq. 3 becomes a seventh order polynomial in T

$$\frac{\Delta K}{K \gamma_{avg} \beta} = \frac{l}{K \gamma_{avg} \beta T_j} + \sum_{i=1}^{6} \frac{\tau_i (\gamma_i \beta_i / \gamma_{avg} \beta)}{T_j + \tau_i} \qquad (4)$$

which is readily solved by digital-computer methods. The general behavior of Eq. 4 is shown in Fig. 2 where we have plotted for U^{235} the "steady-state" period, $T \equiv \omega_0^{-1}$, and the six "transient" periods, $T_j \equiv \omega_j^{-1}$, as a function of reactivity in dollars. It is seen that for a subcritical assembly all seven roots of Eq. 4 are negative, six of these approaching the delayed-neutron periods τ_i in the limit of large negative reactivity. If reactivity is suddenly increased, making the assembly supercritical, the "steady-state" period T becomes positive while the remaining

* A rigorous treatment of reactor kinetic behavior involves explicitly the geometry of the individual chain-reacting system (*1*). However the usual reactor kinetic equations which govern time behavior are developed from an equivalent space-independent, one-group model. In this approximation one assumes that the fundamental space mode of neutron flux within a reactor is preserved, so that kinetic behavior is determined almost exclusively by the delayed neutron characteristics. (At high reactivities—approaching the prompt-critical condition—the mean neutron lifetime characteristic of a given assembly begins to dominate kinetic behavior, but this region is avoided in normal operation.)



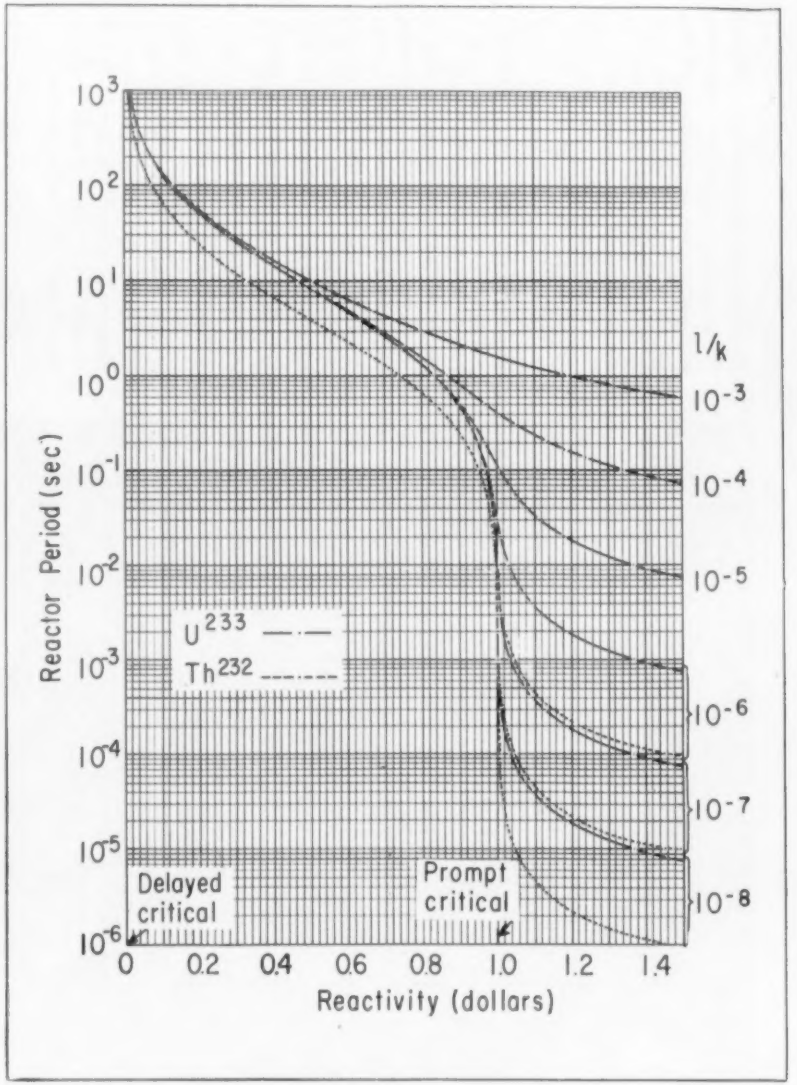


FIG. 1. Reactor stable period-vs.-reactivity relation for (left) U^{235}, U^{238} and Pu^{239} and (right) for U^{233} and Th^{232}. Parameter l/K is "reduced neutron cycle time," where l is prompt neutron lifetime and K is neutron reproduction number for finite geometry

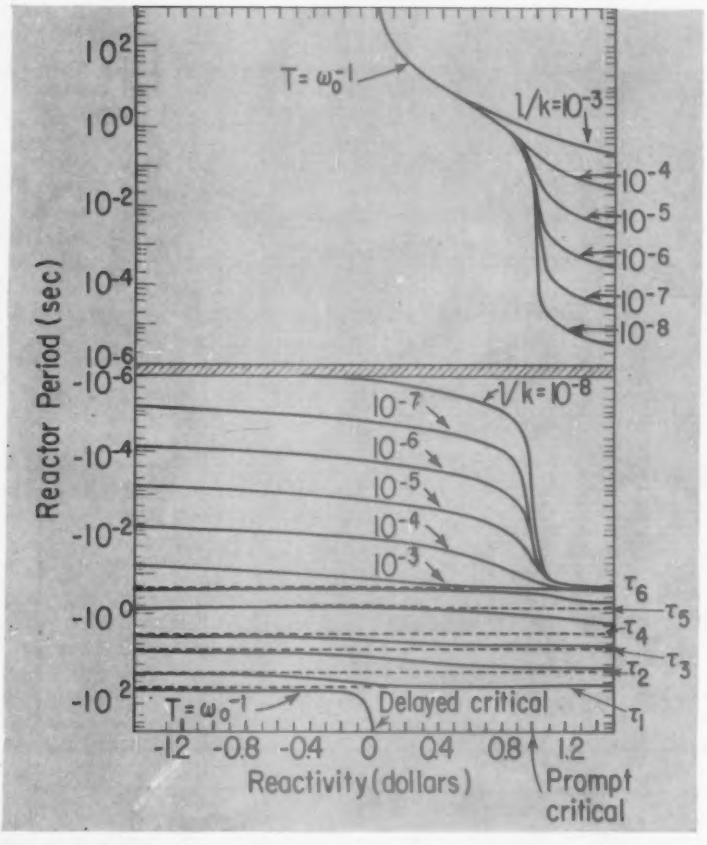


FIG. 2. Reactor "stable"- and "transient"-periods vs. reactivity for U^{235} delayed neutron data of Tables 1 and 2. Dotted lines, $\tau_1 \ldots \tau_6$ are six delayed-neutron mean lives for U^{235}

negative T_i again approach the six delayed-neutron periods, in the limit of very large positive reactivity. The time behavior of neutron density will of course be represented by a superposition of these seven periods, as indicated in Eq. 2.

The quantities γ_{avg} and l/K in Eq. 4 are dependent on individual reactor geometry. (Here l/K is called "reduced neutron cycle time"; dimensionally it is equal to the mean lifetime for fission divided by ν_{avg}, the average number of neutrons per fission.) Thus, for the purpose of general presentation, we have chosen representative values of l/K varying between the extremes of a few milliseconds for a large thermal system to a few "shakes" (10^{-8} sec) for a fast metal system. Also for the purpose of generalization, we have taken γ_{avg} equal to unity.† In any case, the period-reactivity relation is clearly not sensitive to small perturbations in l/K and γ_{avg} for the reactor period $T > 1$ sec—the region where reactors are normally operated.

The first quadrant of Fig. 2 (positive values of both period and reactivity) is the familiar "stable-period" vs. reactivity relation. Because of its practical importance in reactor work this "inhour relation" has been evaluated by digital computer for six fissile species, using the delayed neutron data of Tables 1 and 2. (The factors $\gamma_i\beta_i/\gamma_{avg}\beta$ in Eq. 4 were replaced by the measured relative group abundance values, a_i/a, given in Table 1.) The resulting curves are shown in Fig. 1.‡ Computed values for Pu^{240} were not plotted as these are essentially the same as for Pu^{239} (cf., Pu^{239} and Pu^{240} delayed-neutron data in Table 1). Values for the parameter $l/K \geq 10^{-5}$ sec were not plotted for the "threshold fissioners," U^{238} and Th^{232}, because long neutron lifetimes are not normally characteristic of fast-fission systems.

For all fissionable species, the prompt-critical fiducial $\left(\frac{\Delta K}{K\gamma_{avg}\beta} \equiv 1\right)$ marks the transition from a delayed-neutron-dominated time behavior to a prompt-neutron-dominated time behavior; by definition, the dollar unit of reactivity brings the prompt-critical points for all fissile species into coincidence (cf., Fig. 1, p. 87), which affords certain advantages when making comparisons among the species. For example, from a measurement of period, $T \gg l$, for almost any composite system (containing two or more fissile species) one can bracket the corresponding reactivity in dollars, independent of the effective delayed-neutron fraction for the composite. (A reasonable estimate of relative fission rates in the assembly may then be used to determine reactivity more precisely, if desired.)

For some species, the "pure-isotope" curves in Fig. 1 represent hypothetical limiting cases (viz., U^{238} and Th^{232} for which $K_\infty < 1$). Nevertheless these limiting cases are useful in bracketing extremes of steady-state kinetic behavior; i.e., the effective delayed neutron parameters for a composite assembly will have values intermediate between its component "pure-isotope" values.§ Therefore the period-reactivity relation for a composite assembly must also be intermediate between the appropriate limiting cases given in Fig. 1.

Except for some (usually) secondary effects due to the specific geometry de-

† Although γ_{avg} values for most systems are a few percent greater than unity, the value of γ_{avg} in a fast Pu-metal system can be a few percent less than unity. In certain geometries it is possible to have considerably greater variation in γ_{avg} due to differential leakage between the delayed and prompt neutrons.

‡ Actually the calculations were extended well beyond the reactivity range shown, but such high reactivities are of little interest in general reactor work. The full range of computed numerical values for all nuclides are available on request.

§ In principle, the effective delayed neutron parameters for an arbitrary system can be evaluated by means of a multigroup flux-adjoint calculation (*5*). This method formally takes account of the spatial and energy dependence of delayed neutron effectiveness (also photoneutrons, n,2n, etc., if any) and of mean neutron lifetime in a given geometry. Such calculations are planned for several representative uranium- and plutonium-fueled systems; however detailed numerical computations must await further data on basic multigroup parameters and on delayed neutron energy spectra.

pendence of l and γ_{ave}, photoneutron and $n,2n$ processes, etc., these arguments apply to nearly all composite systems, whether fast or slow, homogeneous or heterogeneous in simple or complex geometries. Thus, for example, the extremes of steady-state time behavior of a fast plutonium-breeding system can be estimated from Fig. 1a, similarly for a U^{233}-Th^{232} system from Fig. 1b.

It is interesting that the "sequence" of inhour curves (i.e., successively increasing reactivity values for a given period) correlates directly with decreasing fission-fragment chain length for the six species as one progresses from U^{238} to U^{233}. This is to be expected since relative group abundance values are determined largely by the so-called "chain length effect"; (cf., Table IV of ref. 4, et seq.). An extreme case in point is U^{238} (with the largest fission-fragment chain length and the highest ratio of short-period to long-period delayed-neutron abundance) which clearly exhibits the greatest departure from "average" kinetic behavior.

Zero-Power Transfer Function

Another useful method of describing the kinetic behavior of a reactor is through its response to periodic variations in reactivity. We assume once again the space-independent one-group model, wherein Eqs. 1 apply. Introducing $\Delta K = K - 1$, these may be rewritten as follows

$$\frac{dn}{dt} = \frac{\Delta K}{l} n - \frac{\gamma_{ave}\beta}{l} n + \sum_i \lambda_i \gamma_i c_i$$
$$\frac{dc_i}{dt} = \frac{(\Delta K + 1)}{l} \beta_i n - \lambda_i c_i \qquad (1')$$

We wish to examine the response of neutron density, n, to a small oscillation of ΔK with time. In the linear or small-amplitude approximation we have for the time variation in ΔK

$$\Delta K(t) = \Delta K_0 \, e^{j\omega t} \qquad j \equiv (-1)^{1/2}$$

and the consequent linear variations of neutron density and delayed neutron precursor density

$$n(t) = n_0 + n_1 e^{j\omega t}$$
$$c_i(t) = c_{i_0} + c_{i_1} e^{j\omega t}$$

where $\Delta K_0 \ll 1$ and $n_1/n_0 \ll 1$; the zero subscripts refer to steady-state values. Substituting the above expressions into Eqs. 1′ gives the simultaneous equations

TABLE 1—Delayed-Neutron Half-Lives, Decay Constants and Relative Abundances*

Group index i	*Half-life (sec)*	*Decay constant* λ (sec^{-1})	*Relative abundance* a_i/a
U^{235}			
1	54.51 ± 0.94	0.0127 ± 0.0002	0.038 ± 0.003
2	21.84 ± 0.54	0.0317 ± 0.0008	0.213 ± 0.005
3	6.00 ± 0.17	0.115 ± 0.003	0.188 ± 0.016
4	2.23 ± 0.06	0.311 ± 0.008	0.407 ± 0.007
5	0.496 ± 0.029	1.40 ± 0.081	0.128 ± 0.008
6	0.179 ± 0.017	3.87 ± 0.369	0.026 ± 0.003
U^{238}			
1	52.38 ± 1.29	0.0132 ± 0.0003	0.013 ± 0.001
2	21.58 ± 0.39	0.0321 ± 0.0006	0.137 ± 0.002
3	5.00 ± 0.19	0.139 ± 0.005	0.162 ± 0.020
4	1.93 ± 0.07	0.358 ± 0.014	0.388 ± 0.012
5	0.490 ± 0.023	1.41 ± 0.067	0.225 ± 0.013
6	0.172 ± 0.009	4.02 ± 0.214	0.075 ± 0.005
U^{233}			
1	55.11 ± 1.86	0.0126 ± 0.0004	0.086 ± 0.003
2	20.74 ± 0.86	0.0334 ± 0.0014	0.274 ± 0.005
3	5.30 ± 0.19	0.131 ± 0.005	0.227 ± 0.035
4	2.29 ± 0.18	0.302 ± 0.024	0.317 ± 0.011
5	0.546 ± 0.108	1.27 ± 0.266	0.073 ± 0.014
6	0.221 ± 0.042	3.13 ± 0.675	0.023 ± 0.007
Pu^{239}			
1	53.75 ± 0.95	0.0129 ± 0.0002	0.038 ± 0.003
2	22.29 ± 0.36	0.0311 ± 0.0005	0.280 ± 0.004
3	5.19 ± 0.12	0.134 ± 0.003	0.216 ± 0.018
4	2.09 ± 0.08	0.331 ± 0.012	0.328 ± 0.010
5	0.549 ± 0.049	1.26 ± 0.115	0.103 ± 0.009
6	0.216 ± 0.017	3.21 ± 0.255	0.035 ± 0.005
Pu^{240}			
1	53.56 ± 1.21	0.0129 ± 0.0004	0.028 ± 0.003
2	22.14 ± 0.38	0.0313 ± 0.0005	0.273 ± 0.004
3	5.14 ± 0.42	0.135 ± 0.011	0.192 ± 0.053
4	2.08 ± 0.19	0.333 ± 0.031	0.350 ± 0.020
5	0.511 ± 0.077	1.36 ± 0.205	0.128 ± 0.018
6	0.172 ± 0.033	4.04 ± 0.782	0.029 ± 0.006
Th^{232}			
1	56.03 ± 0.95	0.0124 ± 0.0002	0.034 ± 0.002
2	20.75 ± 0.66	0.0334 ± 0.0011	0.150 ± 0.005
3	5.74 ± 0.24	0.121 ± 0.005	0.155 ± 0.021
4	2.16 ± 0.08	0.321 ± 0.011	0.446 ± 0.015
5	0.571 ± 0.042	1.21 ± 0.090	0.172 ± 0.013
6	0.211 ± 0.019	3.29 ± 0.297	0.043 ± 0.006

* These are "fast" fission data (2); similar results for "thermal" fission (Table II of 2) are in essential agreement with the above values. Since greater statistical precision was obtained for the fast-fission measurements, these data are recommended for general reactor applications.

$$j\omega n_1 \simeq \frac{\Delta K_0}{l} n_0 - \frac{\gamma_{ave}\beta}{l} n_1 + \sum_i \lambda_i \gamma_i c_{i_1}$$
$$j\omega c_{i_1} \simeq \frac{\Delta K_0}{l} \beta_i n_0 + \frac{\beta_i}{l} n_1 - \lambda_i c_{i_1} \qquad (5)$$

Solving for n_1/n_0 in Eqs. 5 and neglecting terms in second order we have

$$\frac{n_1}{n_0} = \frac{\Delta K_0}{\gamma_{ave}\beta} W(j\omega) \qquad (6)$$

where $W(j\omega) \equiv$

$$\left[1 + \frac{1}{\gamma_{ave}\beta}\left(j\omega l - \sum_{i=1}^{6} \frac{\gamma_i \beta_i \lambda_i}{j\omega + \lambda_i}\right)\right]^{-1}$$

$W(j\omega)$ is often called the zero-power reactor transfer function. The dynamic response of a reactor can be expressed in terms of the amplitude and phase angle of W as a function of the impressed frequency, ω. Also a measurement of W can be used to determine

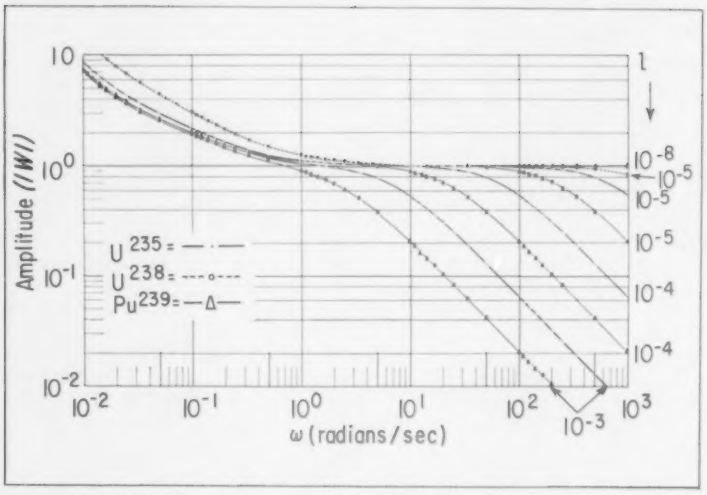


FIG. 3. Reactor-transfer-function amplitude response vs. frequency for U^{235}, U^{238} and Pu^{239}. Parameter *l* is prompt neutron lifetime

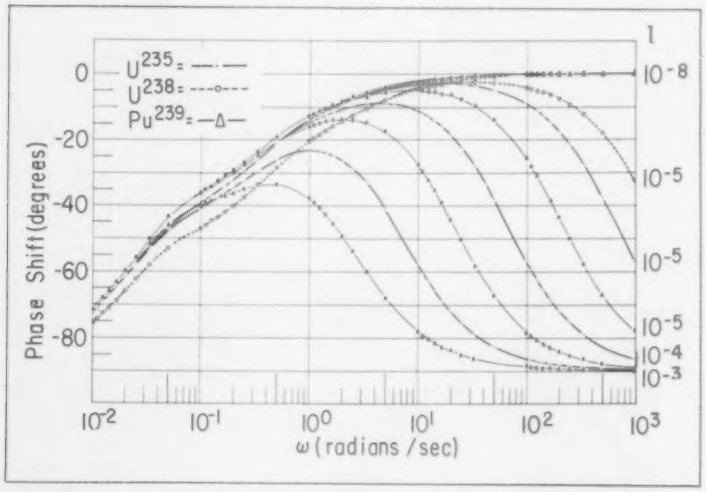


FIG. 4. Reactor-transfer-function phase-shift [Φ = arctan Im (W)/Re (W)] response versus frequency for U^{235}, U^{238} and Pu^{239}

directly the prompt neutron lifetime in a given reactor (δ). The coefficient of W in Eq. 6 is the amplitude of the impressed reactivity oscillation, expressed in units of dollars (assuming $K \simeq$ unity).

TABLE 2—Total Delayed-Neutron Fractions

Nuclide	β
Pu^{239}	0.0021
U^{233}	0.0026
Pu^{240}	0.0026
U^{235}	0.0065
U^{238}	0.0157
Th^{232}	$\sim$0.02$_2$

As in the case of the period-reactivity relation, we have chosen representative values of the prompt-neutron lifetime, l, varying between 10^{-3} and 10^{-8} sec, and we have taken γ_{avg} equal to unity. Also the factors $\gamma_i\beta_i/\gamma_{avg}\beta$ in Eq. 6 are replaced by measured relative group abundance values, a_i/a, and the measured β values (Table 2) for each of the six fissionable materials were used. The resulting amplitude and phase-shift response versus frequency are shown in Figs. 3 and 4 for the three main fissionable species, U^{235}, Pu^{239} and U^{238}. Calculated values for U^{233}, Pu^{240} and Th^{232} were not plotted since the curve for Th^{232} is similar to that for U^{238} and the curves for U^{233} and Pu^{240} are similar to Pu^{239}. As before, long neutron lifetimes (large l) are not plotted for U^{238}.

For ω greater than about 1 radian/sec, fast metal reactors are seen to exhibit a characteristic frequency-independent response with amplitude approaching unity, in phase with the impressed reactivity variation. A much stronger dependence of response characteristics on type of fissile material and on neutron lifetime is seen in intermediate and "slow" reactors. Available data on transfer-function measurements, such as that for the Argonne CP-2 reactor (*6*) are in agreement with the calculated results in Figs. 3 and 4.

In the general case of a reactor operating at power, there will be coupling between power level and reactivity. Such "feedback" mechanisms (temperature coefficients, etc.) are governed by individual reactor characteristics and are not readily susceptible to generalization. The experimental study of these mechanisms, and possible resulting instabilities, usually require transfer-function measurements at several power levels. Nevertheless, the "universal" zero-power transfer functions have proved instructive in understanding (and estimating) the dynamic behavior of various types of chain-reacting systems.

* * *

Gratitude is expressed to Clarice W. Cox for coding and programming assistance on the Los Alamos IBM-704 computer.

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NOTE ADDED IN PROOF. The "waiting time" required for accurate reactivity determination by the asymptotic ("stable") period method has been investigated recently by B. J. Toppel (Paper 5-10, Meeting of the American Nuclear Society, June, 1958). He finds that under common experimental conditions, several minutes may be required following a step change in reactivity to achieve 1% accuracy in the period.

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A Matrix to Correct for Scintillator Escape Effects

By E. G. RAWSON and D. V. CORMACK, *University of Saskatchewan and Saskatoon Cancer Clinic, Saskatoon, Canada*

Scintillation counters do not respond directly to gamma rays but rather to the electrons which those gamma rays produce in a crystal. Generally, some of the gamma's energy escapes the crystal; so even if monochromatic gamma rays are incident the resultant pulse-height spectra are distributed over a range of pulse heights. If the gamma undergoes a Compton scattering the degraded photon may escape from the crystal; if the absorption process is photoelectric, there is a certain probability of escape for the X-ray produced when the ejected electron is replaced. In addition, of course, there are normal statistical spreads in the optics of the crystal and gain of the photomultiplier, etc. To compensate for these effects, corrections must be applied to a measured pulse-height distribution to relate it to the true spectrum.

The statistical or "Gaussian" correction has been dealt with by several writers (*1*, *2*). Axel (*3*) has developed the theory and estimated corrections for escape of iodine fluorescent X-rays. Maeder *et al* (*4*) and Berger and Doggett (*5*) have done calculations on Compton escape. However, in the energy range 0–400 kev, Maeder *et al* have calculated Compton tails for only two energies (250 kev and 375 kev), and Berger and Doggett's calculations include only one energy (279 kev) in that range. To use these calculations in the matrix correction outlined below would involve interpolations and extrapolations highly susceptible to error. It was decided that more extensive calculations of Compton escape processes were necessary, as described in a later section.

The question arises as to the order in which the three corrections outlined above should be applied. Assuming that one must correct for distortions in reverse order to that in which they occurred, we made the Gaussian correction first. The other two corrections should be made simultaneously, since Compton and K-escape processes occur independently and parallel—that is, the number of photons which undergo one or the other is dependent solely upon the number of incident photons since those photons which suffer a Compton escape cannot then go on and suffer a K X-ray escape, and *vice versa*.

Preparing the Matrix

Given the output spectra produced by monochromatic radiation incident on a crystal one can construct a forward matrix which operates on a true photon distribution to yield the distribution of light pulses at the photocathode of the multiplier tube. To obtain the contribution due to the escape of Compton-scattered photons, distributions such as those in Fig. 1 were divided into 20-kev intervals. The area under the curve in each interval was measured and the resulting value multiplied by a factor (to be explained later) which allows for the escape of multiply-scattered radiation. For energies where there is no contribu-

How to Use These Matrices

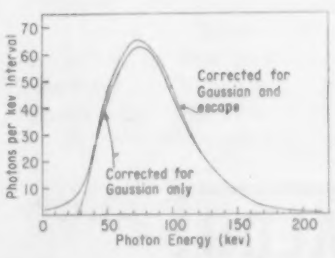
The two matrices presented here permit adjustment of either scintillation (pulse-height) spectra or incident photon spectra given one or the other. The forward matrix (left) operates on incident photon energy to yield scintillation spectral distributions. The inverse matrix (right) effects the inverse transformation —it corrects scintillation spectra to give incident photon spectra.

For example, the curve below shows the scattered spectrum produced by 280-kvp X-rays in water. The solid curve is the measured spectrum, already corrected for photomultiplier statistical spreading. Finding the correct incident photon spectrum is a 3-step operation:

- ***First*, read the values of the ordinate (photons per kev energy interval) from the spectral curve and align them vertically to form a one-column matrix; for example, the ordinate at 30 kev is 10, which would be the first term in the column.**
- ***Second*, multiply each value in the one-column matrix successively by each number in the corresponding row (horizontal line) of the inverse matrix—the 30-kev term by the 30-kev row, the 50-kev term by the 50-kev row, and so on. Thus the 30-kev value, 10, is multiplied successively by the 2 terms in the 30-kev row of the matrix, −0.0704 and 1.0704.**

There is also a certain probability that photons with initial energies over 30 kev will be only partially absorbed so as to appear in the 30-kev range. To correct for this energy degradation, multiply the values of the ordinate at each higher photon energy interval (50, 70, 90, 110 kev, etc.) by the corresponding value in the 30-kev column of the matrix. Thus the ordinate at 50 kev, 43, should be multiplied by the number in the "50" row and the "30" column of the matrix, −0.0882; similarly, the 70-kev value should be multiplied by −0.0530, and so on, to form another one-column matrix.

- ***Finally*, sum the new values vertically to get the correct input spectrum. This spectrum is plotted as a dotted line below.**



Correction of spectrum of 280-kvp scattered radiation. A. corrected for Gaussian effect only, B. corrected also for Compton and K-escape using inverted matrix

Inverse Matrix—To Correct Measured Spectrum for Compton and K X-Ray Escape

Center of Photon Energy Interval (kev)

Energy Corresponding to Center of Pulse-height interval (kev)

Multiply tabulated values by 10^{-4}

	10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	330	350	370	390
10	10000																			
30	−704	10704																		
50	−993	−822	11814																	
70	+41	−530	−466	10955																
90	+9	0	−339	−243	10574															
110	+4	−66	+13	−190	−143	10382														
130	+8	−59	−44	+4	−118	−96	10301													
150	+11	0	−123	+1	+2	−78	−70	10256												
170	+5	+9	−66	−85	+1	+1	−67	−60	10262											
190	−4	+3	−7	−141	−26	0	+1	−50	−41	10281										
210	−13	−10	−2	−51	−123	0	0	0	−39	−35	10344									
230	−33	−27	−19	−15	−101	−98	0	0	0	−28	−26	10438								
250	−58	−50	−46	−20	−46	−158	−38	0	0	0	−18	−15	10617							
270	−91	−73	−73	−47	−28	−84	−183	0	0	0	0	−12	−10	10899						
290	−130	−111	−108	−82	−52	−50	−125	−162	0	0	0	0	−8	−5	11284					
310	−161	−142	−143	−117	−84	−53	−77	−225	0	0	0	0	0	−1	0	11614				
330	−191	−174	−179	−146	−121	−88	−70	−110	−201	−89	0	0	0	0	0	0	12175			
350	−231	−205	−215	−185	−158	−126	−93	−87	−146	−246	−38	0	0	0	0	0	0	12776		
370	−243	−220	−238	−209	−186	−159	−130	−95	−113	−173	−269	0	0	0	0	0	0	0	13278	
390	−251	−225	−252	−226	−204	−183	−157	−123	−105	−142	−193	−230	0	0	0	0	0	0	0	13772

Forward Matrix—To Modify True Spectrum for Compton and K X-ray Escape

Energy Corresponding to Center of Pulse-Height Interval (kev)

Center of Photon-Energy Interval (kev)

Multiply tabulated values by 10^{-4}

	10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	330	350	370	390
10	10000																			
30	658	9342																		
50	886	650	8464																	
70	32	480	360	9128																
90	21	32	280	210	9457															
110		68		170	130	9632														
130		57	39		110	90	9708													
150		8	102			74	66	9750												
170			58	76			63	57	9744											
190	5	4	12	126	24			48	42	9727										
210	14	12	7	48	113				37	33	9667									
230	35	27	19	17	93	90				26	24	9580								
250	62	48	38	21	44	144	35				16	14	9418							
270	94	71	60	41	27	76	163					11	9	9175						
290	131	103	87	68	45	45	109	140					6	4	8862					
310	158	128	112	94	70	46	66	189						1		8610				
330	180	150	134	115	96	71	55	90	161	71							8213			
350	208	169	153	140	120	96	72	68	112	188	29							7827		
370	211	176	163	152	138	117	96	71	84	127	196								7531	
390	211	176	167	158	146	131	112	88	75	101	136	160								7621

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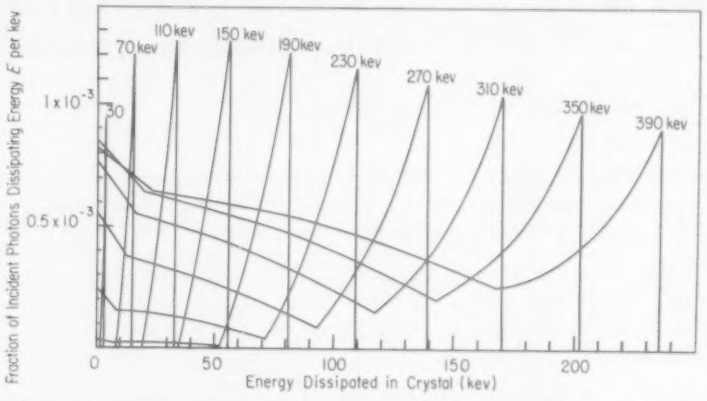

FIG. 1. Calculated energy-loss distributions in a cylindrical NaI(Tl) crystal, 1¾ × 2 in., allowing for the escape of once-scattered photons

tion from K-escape, these Compton contributions form the nondiagonal matrix elements. For example, an incident photon of 350 kev produced, on the average, 0.0120 pulses corresponding to energies between 80–100 kev, this contribution being entirely due to escape of Compton-scattered radiation.

The fraction of incident photons producing an escaping K X-ray was taken from Axel's data and confirmed by our experiments. We assume that all escaping X-rays have an energy of 30 kev. Thus if a photon produces an escaping X-ray, it will appear in the scintillation spectrum at a point 30 kev below its incident energy. Since we used 20-kev intervals, some difficulty arises because a photon with an energy at the center of an interval produces a K-escape pulse at the energy separating the two intervals below. For example, a 150-kev photon would give pulses at 120 kev, the value separating the 100–120 and 120–140 kev intervals. For a continuous spectrum, however, we can split each photon energy interval in half, so that each half contributes to a different pulse interval lower down. For example, incident photons with energies from 140–160 kev produce, on the average, 0.0074 pulses per incident photon between 100–120 kev, and 0.0066 pulses between 120–140 kev. At photon energies below 100 kev, the Compton and K-escape contributions overlap, so the values shown in the matrix are the sum of the two.

The sum of the values on any horizontal row of the matrix (including the value of the diagonal) must represent the number of output pulses per incident photon, which equals the crystal efficiency factor. This fact allows one to determine the diagonal value by subtracting the sum of all the nondiagonal elements from the efficiency factor. The values on the diagonal give the fraction of the incident photons which produce output pulses corresponding to their full quantum energy.

Correction matrix. All that is now required to form the final correction matrix is to invert the forward matrix. The inversion is greatly simplified by the fact that the matrix is triangular and can therefore be coverted by a stepwise procedure. The inverted matrix is also triangular. Note that the diagonal values are much larger than any of the other values, and that there are no violent fluctuations such as characterize the inverted matrix for the Gaussian

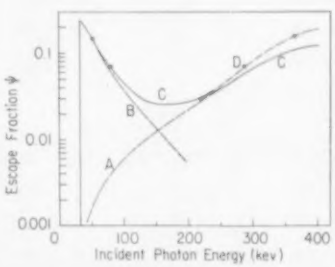

FIG. 2. Plot of the escape fraction—the fraction of incident photons which escape after dissipating part of their energy in the crystal. A. Calculated for once-scattered photons. B. Taken from Axel's data (3) for K-escape. C. Sum of A and B. D. Curve C corrected for multiply scattered radiation. Experimental points are shown as circled dots

effect. Therefore, small errors in the measured input spectrum will not produce unduly large variations in the output spectrum.

Escape Data

Now let us consider the method used to evaluate Compton escape. One possibility involves exact calculation of the first Compton interactions of incident photons and estimation of the results of further interactions (*4*). Alternatively, the Monte Carlo method can be used to calculate the response functions for NaI(*Tl*) crystals of several sizes and for several incident energies. At present, the Monte Carlo method is the only practical way to calculate the effects of multiple interactions; it is obviously preferable in many ways, but it requires long, expensive calculations on an electronic computer for accuracy. Because of the time, expense, and quantity of data required for a Monte Carlo project, we decided to calculate exactly the amount of once-scattered radiation which escapes the crystal and to modify this with experimental data to correct for multiply-scattered radiation. Calculations were performed for radiation incident on one end of a cylindrical NaI(*Tl*) crystal $1\frac{3}{4}$ in. dia and 2-in-long along the central axis. Calculations for twenty photon energies in the range 0–400 kev were performed on an electronic computer.

Fig. 1 shows the resulting spectral distributions of energy losses in the crystal produced by photons which escape after a single Compton collision; the escape of multiply-scattered photons is neglected. The area under each of these curves represents the probability $\psi_{1(k_0)}$ that an incident photon will carry a fraction of its energy out of the crystal after a single Compton interaction. Values of $\psi_{1(k_0)}$ are plotted as curve A of Fig. 2.

Curve B of Fig. 2 shows the probability $\psi_{2(k_0)}$ that an incident photon will undergo K escape. Values of $\psi_{2(k_0)}$ were taken from Axel's paper for "very good geometry." The sum $\psi_1 + \psi_2 = \psi$, the combined probability that an incident photon will not deliver its full energy to the crystal (neglecting the escape of multiply-scattered photons). Values of this "escape fraction," ψ, are shown as curve C in Fig. 2.

In order to correct the values of ψ for multiple-scattering, we used nearly monochromatic radiation from an X-ray generator to obtain spectra at energies from 220–400 kev.

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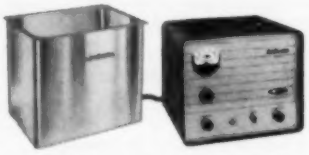

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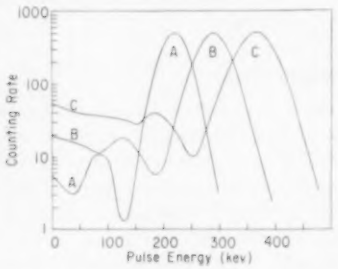

FIG. 3. Measured spectra of nearly monochromatic radiation. A, 210 kev; B, 287 kev; C, 365 kev

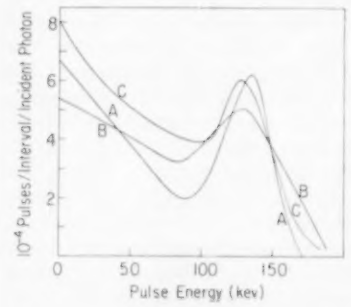

FIG. 4. Comparison of shapes of Compton escape tail. A. Calculated for 280 kev considering once-scattered radiation and corrected by factor (ψ^s/ψ). B. Measured for nearly-monochromatic radiation of 287 kev. C. Taken from Berger and Doggett *(5)*

radiation with energies of 210, 287 and 365 kev are shown on a semilogarithmic scale in Fig. 3. The area under each of these curves (including the main peak) represents the number of photons that undergo interaction in the crystal; that is, the number of incident photons multiplied by a crystal efficiency factor, $(1 - e^{-\mu t})$, where μ is the total absorption coefficient in NaI(*Tl*) and t is the crystal thickness. In our crystal, the efficiency factor is unity for energies up to 150 kev and decreases to 0.892 at 390 kev. The area under the low-energy tail of the curve divided by the area under the whole curve represents the fraction of interacting photons which do not contribute their full energy to the crystal. This ratio was multiplied by the crystal efficiency factor to give an "experimental escape fraction," ψ^s.

These "experimental" values of ψ^s are plotted as points on Fig. 2 at their respective energies. It will be noted that the point at 210 kev is very close to the calculated curve but that the points at 287 and 365 kev are higher, indicating an appreciable contribution

from the escape of multiply-scattered photons. Curve D of Fig. 2 is a smooth curve drawn through these points following the shape of curve C. It was decided to multiply the calculated ordinates of the Compton escape spectra of Fig. 1 by the factor (ψ^x/ψ) to make the escape fractions agree with experimental data. This correction factor changes from 1.07 at 240 kev to 1.52 at 400 kev.

Fig. 4 shows the calculated escape spectrum for 280 kev, (curve A) modified as above and smeared out to simulate the Gaussian spreading, compared with the measured Compton tail for 287-kev radiation (curve B). The shapes of the two curves agree closely enough to justify the use of the calculated Compton escape data for correcting measured spectra. Berger and Doggett's curve (*5*) for 279 kev (curve C of Fig. 4) also supports this conclusion.

Experimental spectra were also obtained for low energies in order to check the *K*-escape fractions calculated by Axel, since Ehrlich (*2*) reported finding no *K*-escape in her measurements. We measured the output spectrum produced by: (1) Pb fluorescent *K* radiation (77 kev) and (2) highly-filtered X-ray beams giving effective energies of 54 kev and 70 kev. The measured spectra for the Pb X-rays and the 54-kev radiation (Fig. 5) show clearly the secondary peak due to the escape of iodine, which is about 30 kev below the photopeak in both cases. The escape fractions calculated from these spectra are plotted in Fig. 2, and show excellent agreement with Axel's theoretical values and also with Bell's (*6*).

* * *

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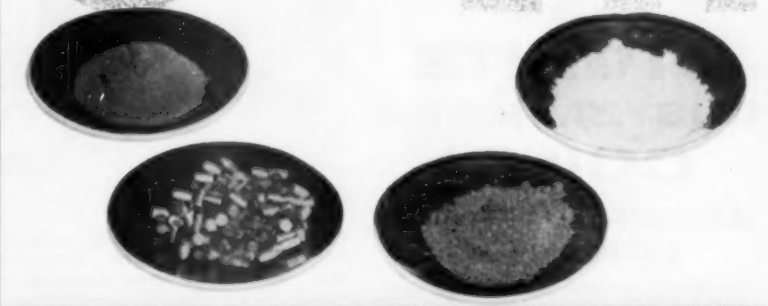

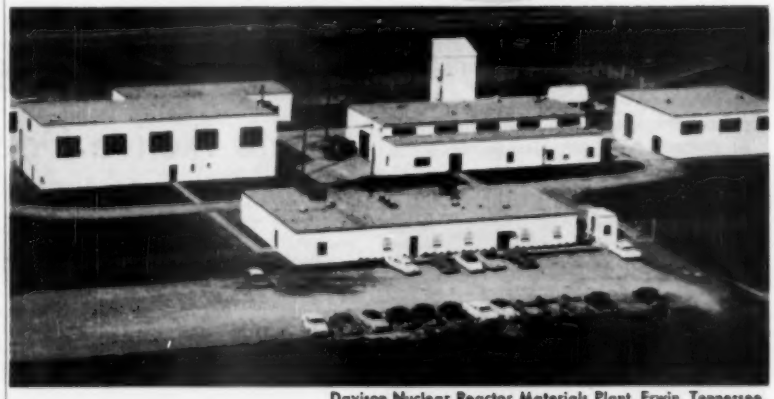

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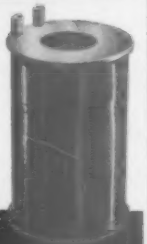

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FIG. 1. Beta-ray camera with top seal (and attached handle, thermocouple gage, and air inlet valve) removed. Film cassette and its mounting ring are on table near seal. Aperture and holder are visible inside the camera

Pinhole Camera Maps Beta-Active Deposits

By L. E. PREUSS and G. JENKINS
Physics Department
Edsel B. Ford Institute for Medical Research
Detroit, Michigan

An evacuated pinhole camera can study very active deposits of beta-ray-emitting radioisotopes without the problems of contamination and radiation exposure involved in autoradiography and surface scanning. Very high concentrations of radioactive material can be used conveniently with beta-ray cameras because shielding—both internal and external—is easily incorporated into the camera design.

The camera (Fig. 1) is a vacuum-sealed vertical cylinder. The inside of the cylinder is threaded to permit continuous adjustment of aperture and film location, thus providing a wide range of object and image distances. In addition, the cassette is designed to hold a wide range of film and plate sizes. A shutter permits loading and adjusting the camera before exposure,

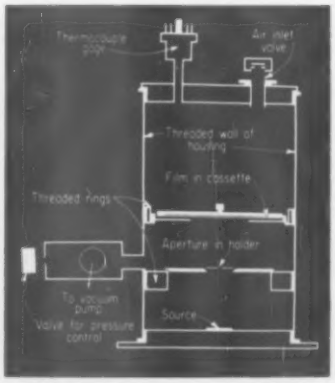

FIG. 2. Diagram of camera showing relative positions of source, aperture, and film holder. True planar apertures consisting of holes in very thin plates or of intersecting cones were used, since cylindrical[3] apertures cause vignetting

as well as serving to time short exposures of very hot specimens. Because a pinhole geometry can provide magnification, small sources can be studied in detail. The beta-ray camera's image resolution is ~10 microns, which roughly approaches the 1-2-micron resolution of gross-apposition autoradiography. In addition, the camera permits quantitative assay in terms of the corresponding emulsion density, because a direct relation exists between the photographic emulsion density and beta emission for the linear portion of the Hürter-Driffield curve. Calibration of the film exposure and development procedure with uniform standard radioactive deposits allows accurate assay of all parts of the image.

Best for Hot Sources

We had two other methods for deposition studies available: Gross-apposition autoradiography and small-area scanning. Each method had its own advantages and disadvantages. Autoradiography was best suited to applications involving relatively small amounts of radioactive material (10^{-5} mc or less), but when the activity levels were high, problems of contamination, fogging, and excessive personnel dosage during handling were impossible to eliminate. Determining proper exposure time was a particular problem with highly active specimens. Also, contact autoradiography is not a satisfactory nondestructive test; the unavoidable abrasion and damage during autoradiography invariably changed the structure of the fragile deposit and sometimes produced serious contamination hazards.

Small-area scanning, although reasonably accurate, does not match the resolution of the beta-ray camera. The tedious scanning techniques at best provide a series of widely-spaced contour lines instead of a continuous image of the isotope's surface concentration. In addition, scanning, like autoradiography, involves precise handling of highly active sources, a job not easily done remotely.

The shortcomings of both methods point up the advantage of using the beta-ray camera to study very hot sources, because the camera eliminates manipulation of the source under darkroom conditions, and permits short, exact exposures.

Using the Camera

In Fig. 3 we compare three exposures of the same planchet containing P^{32}. One photo was taken with a conventional camera, one with the beta-ray camera, and one by gross-apposition radiography. To make the beta-ray camera exposure, we positioned the source and reduced air pressure inside the camera to 45 microns of Hg, then exposed the plate (Kodak X-ray No-Screen emulsion) for 16 hr at a camera aperture of 163 microns. Camera magnification was unity, although higher magnifications could be obtained.

The camera's resolution is dependent on object distance, image distance, and aperture radius. The resolution improves as the ratio of image/object distance increases, but is limited by the aperture diameter as magnification approaches infinity.

We found that air absorption and scattering of the betas reduces image sharpness and prolongs exposure times, so we usually evacuate the camera. The greatest improvement in image quality for the camera geometry used (camera depth ~5 cm) occurred between atmospheric pressure and about 1 mm of Hg; further pressure reduction produced only slight improvement in image sharpness and resolution.

Like other methods, the beta-ray camera technique has its particular disadvantages; among them are the long exposures needed, the instrumentation required, and the necessity for meticulous positioning of source, aperture, and film.

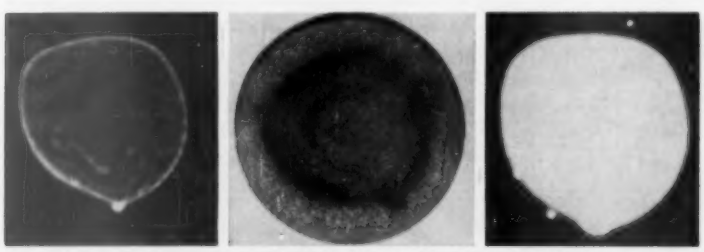

FIG. 3. Three exposures of planchet of P^{32}. Left, beta-ray pinhole photo; center, conventional photo; right, gross apposition autoradiogram (note flaking of deposit). Contrast fine structure visible in pinhole exposure with lack of detail in overexposed autogram; both were exposed 16 hr

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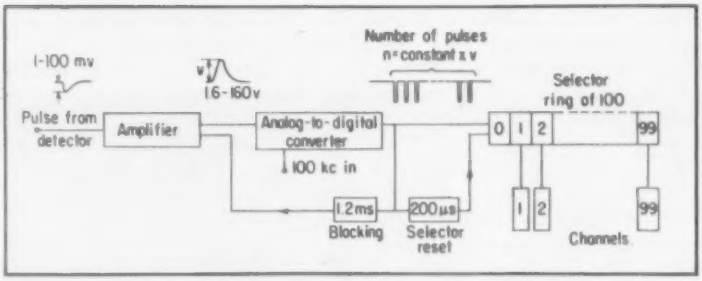

FIG. 1. Single 99-channel pulse-height analyzer. Speed is 800 cps and input sensitivity is 1–100 mv

Slow, Simple 99-Channel Pulse-Height Analyzer

By GERT JENSEN, KAI WILSKY, PREBEN HOLMGREEN JENSEN and FLEMMING THOMSEN

The Finsen Laboratory, Copenhagen, Denmark

We have constructed a slow, comparatively simple 99-channel pulse-height analyzer. Since the analyzer was intended for low-level-activity radiobiological work, long-term stability was emphasized rather than speed.

The analyzer (Fig. 1) follows the analog-to-digital conversion principle introduced by Wilkinson.* One of the two delaying networks resets the channel selector 200 μsec after receipt of the last pulse in a trail of pulses; the other network releases the amplifier blocking.

The amplifier consists of two Chase-Higinbotham amplifying stages, each with 20-db gain followed by two cascode stages with 12 db. The bandwidth is 5 kc–2.5 Mc. The amplifier blocking is performed between stages 2 and 3. The output pulse corresponding to channel 99 is chosen as high as 150 volts.

The analog-to-digital converter is similar to Wilkinson's, using a conventional Miller time-base circuit. The internal frequency is 100 kc.

The channel selector (Fig. 2) is very simple. It consists of a ring scaler with 100 elements.† A 4-dekatron channel is coupled to each element by a passive integrating network formed by a 1-megohm resistor and ~65 μμf (capacity of coaxial cable and channel

* D. H. Wilkinson, *Proc. Camb. Phil. Soc.* **46**, 508 (1949).

† T. K. Sharpless, *Electronics* **21**, No. 3, 122 (1948).

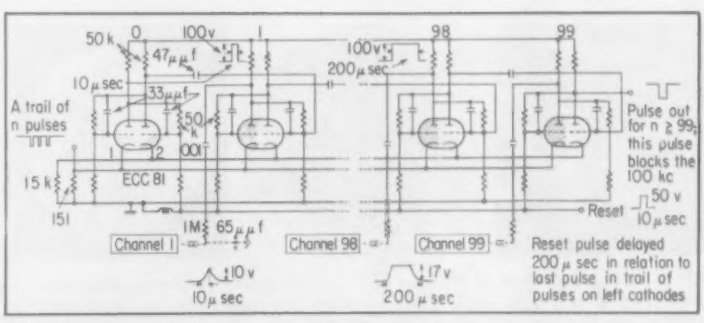

FIG. 2. Channel selector consisting of ring scaler with 100 elements

input). A trail of n pulses applied to the left cathodes moves the "abnormal" state (element 0 in Fig. 2) n steps. All channels with numbers lower than n receive a pulse of 10-μsec rise time and <10-volt amplitude, which is too small to be recorded. Only channel n receives a pulse that has sufficient amplitude and duration to be counted. Here the pulse duration (200 μsec) is given by the delay time of the selector reset pulse. The pulse shapes in Fig. 2 are drawn for $n = 98$.

Counting speed with 100-kc internal frequency is 800 cps. Total power consumption is 1.6 kw. Channels and selector elements are constructed as plug-in units. The complete instrument occupies a space of 180 × 40 cm and 200 cm high. A detailed description of the analyzer has been given elsewhere.‡

‡ P. G. Jensen, Kai Wilsky, P. Holmgreen Jensen, Flemming Thomsen, *Ingeniøren International Edition* **1**, No. 2, 38 (1958).

Photovoltaic Gamma-Ray Dosimeter

By J. W. MOODY, G. L. KENDALL and R. K. WILLARDSON
Battelle Memorial Institute, Columbus, Ohio

Both photoconductive and photovoltaic devices are now being used to detect and measure light intensities or to convert solar energy into electrical energy. Such devices depend upon the excitation of electric charge carriers by radiant energy and, within certain limits, their response is proportional to the intensity of the incident energy. The energizing radiation need not be visible; photosensitive semiconductors are also sensitive to gamma-rays, X-rays, protons, neutrons, etc., and they can be used to detect and measure such radiations.

For example, some devices utilize the photoconductive response of cadmium sulfide and selenide crystals to measure the intensities of X-rays and visible light (*1*) and a sandwich detector (*2*) of two photovoltaic cells and a NaI(Tl) scintillator has been used to monitor gamma radiation fluxes of 10 r/hr or higher. Photovoltaic cells are particularly interesting for gamma-ray dosimetry because of their stability and wide range of response (10–10^{10} rep/hr). Essentially all that is required is a calibrated photovoltaic cell and a sensitive voltmeter. The two components are connected with whatever length of shielded electrical leads is convenient.

Testing the Cell

The particular photovoltaic cell we studied was a commercially available silicon solar cell.* The cell consists of an n-p junction formed by the diffusion of boron into 0.1 ohm-cm, n-type silicon. The boron diffusion produced a high concentration of carriers in the p-type surface layer.

We used a Co^{60} gamma-ray source to give a maximum dose rate of 1.1×10^5 rep/hr. The variation of dose rate as a function of distance above the water-shielded Co^{60} gamma-ray source was calculated by the method described by Lewis, et al (*3*). Because we ignored scattering and build-up effects in our calculations, the calibration could be in error by as much as 20%.

The range of photon fluxes was extended beyond that available from the Co^{60} source by use of a 60-kv X-ray machine. Since there was a large uncertainty in the determination of the X-ray flux because of the absorption of soft X-rays, these data were arbitrarily normalized to the Co^{60} results by multiplying the photovoltages obtained with X-rays by a constant factor, making the two types of exposure equivalent. Although the procedure is perhaps not strictly legitimate we chose it to present data over a wide range of flux and because there were uncertainties in the determination of the energy and flux of the X-rays.

Normalization of the data does not affect our conclusions regarding the sensitivity of the device. The fact that such a procedure was necessary does indicate that the response of the cell is dependent on the energy of the exciting radiation. This conclusion

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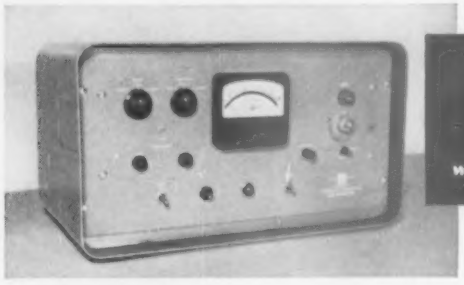

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This article starts on page 101

has been verified recently by Scharf (*4*). He finds that the photovoltage for the same exposure rate decreases with increasing photon energy. This is due to the decreased absorption of the higher energy radiations. From 200 kev to 1.25 mev Scharf finds only a very small dependence of photovoltage on photon energy for silicon solar cells.

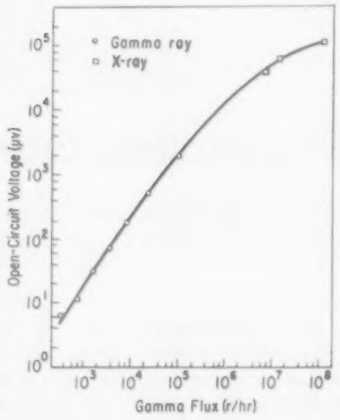

FIG. 1. Open-circuit voltage of silicon solar cell under irradiation

Fig. 1 shows the open-circuit voltages of the solar cell as a function of photon dose rate. Over the linear range (10^2–10^7 rep/hr) the internal impedance of the cell remained constant at 600 ohms. At the highest intensity of gamma-ray dose rate (1.1×10^5 rep/hr) the matched-load power output of the cell is 10^{-10} watts. Above 10^7 rep/hr the response of the cell begins to decrease and to approach the saturation value of 0.4 volt. However, the data indicates sensitivity of response to nearly 10^{10} rep/hr.

Better Materials

The simplicity of the equipment and the accuracy and speed of measurement make an application to gamma-ray dosimetry particularly appealing. It should be pointed out that the results described here were obtained on a commercial unit specifically designed for the efficient conversion of light to electrical energy and that significant advantages may be gained by changing the design and parameters of the cell to be more applicable to gamma-ray dosimetry. For example, a cell could be fabricated whose linear response would be in higher ranges of gamma-ray

dosages than the silicon cell described here, simply by using material of lower minority-carrier lifetime. The use of semiconductors of higher energy gap than silicon would also shift the linear response to higher dose rates by increasing the saturation voltage.

The requirements of low minority-carrier lifetime and high energy gap are found in many of the new compound semiconductors. Thus, photovoltaic cells constructed of gallium arsenide, aluminum antimonide or cadmium telluride should provide a sensitive, convenient method of mapping gamma-ray fields or determining gamma- or X-ray dosages.

The photovoltaic cell would be susceptible to radiation damage arising primarily from the displacement of atoms by Compton electrons. However, various studies of the effect of gamma radiation damage on *p-n* junctions indicate that damage would be negligible in a reasonable length of time, except in the highest gamma fluxes. For the particular cell used in our studies, we estimate that a total dose of about 10^9 roentgen would be necessary to produce a measurable effect. This limit could be raised by design and material considerations. Even if the cell suffered damage after prolonged exposure, it could be healed by proper annealing.

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4. K. Scharf, *Bull. Am. Phys. Soc.*, Series III, **3**, No. 4, 261 (June, 1958)

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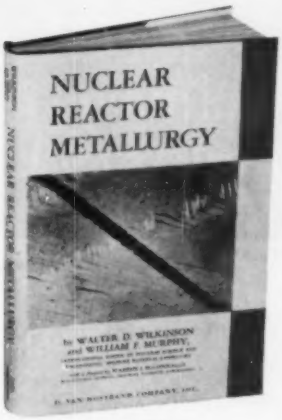

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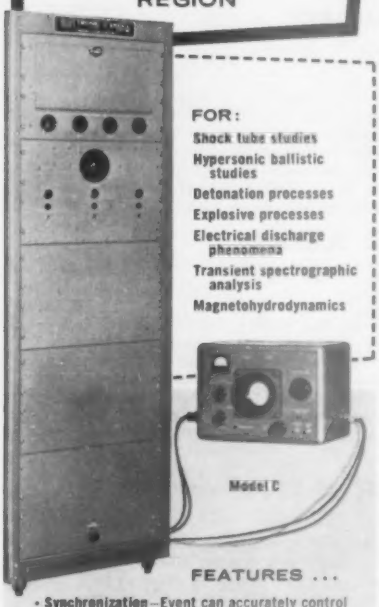

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NUCLEAR ENGINEERING NOTES

Improving Xe Poison Prediction

An improved method for using analog devices to compute and predict xenon poison effects in reactors has been proposed in a recent paper fron India.* The heart of the scheme is to run the analog computer on an accelerated time scale during both the Xe-poison computation and prediction phases. Previously xenon poison computers have used analog computers to solve the xenon differential equations continuously on a real time scale. For prediction, the computer was run on an accelerated time scale so as to obtain the required information in a short time. Operating an electronic analog in this way has disadvantages:

- On a real-time scale the large half-lives of Xe^{135} and I^{135} require very large RC integrating time constants. Stable condensers with high leakage resistances are available, but the currently available resistors of the order of 10^{10} ohms are not stable enough. Amplifier drifts can also produce errors.
- In the event of power failure or a component fault, all the stored information can be lost.
- Prediction of xenon concentration for proposed power variation schedules which are at all complicated is difficult for these computers.

The Indian scheme neatly avoids these problems by operating the analog computer only when the xenon information is needed (e.g., at shutdown or change of power). At all other times during reactor operation the flux variation data is recorded continuously by a conventional strip chart recorder, using conducting ink, with normal chart paper. Whenever a xenon poison calculation is wanted the stored information is fed to an analog computer running on a greatly accelerated time scale. In this way the analog brings itself up to date in a matter of a few minutes and then can easily go on to predict the effect of a future power variation schedule on xenon concentration. This operating arrangement avoids the four difficulties listed above.

The analog reads the strip chart data through a curve follower, which is a modified strip recorder. The curve follower reads the chart at a rate 240 times faster than real time. Under normal reactor operating circumstances the error introduced by the device in the calculation is less than 1% (the curve follower being the main source of error). This is small enough so that the final accuracy of the calculation will depend only on the accuracy of the physical constants and the approximations used for the reactor flux distribution and the calculation of the xenon reactivity effect.

* M. M. L. Bulati et al, Second U. N. Conf on Peaceful Uses of Atomic Energy, P/1627.

Decontamination of Molten Th-U

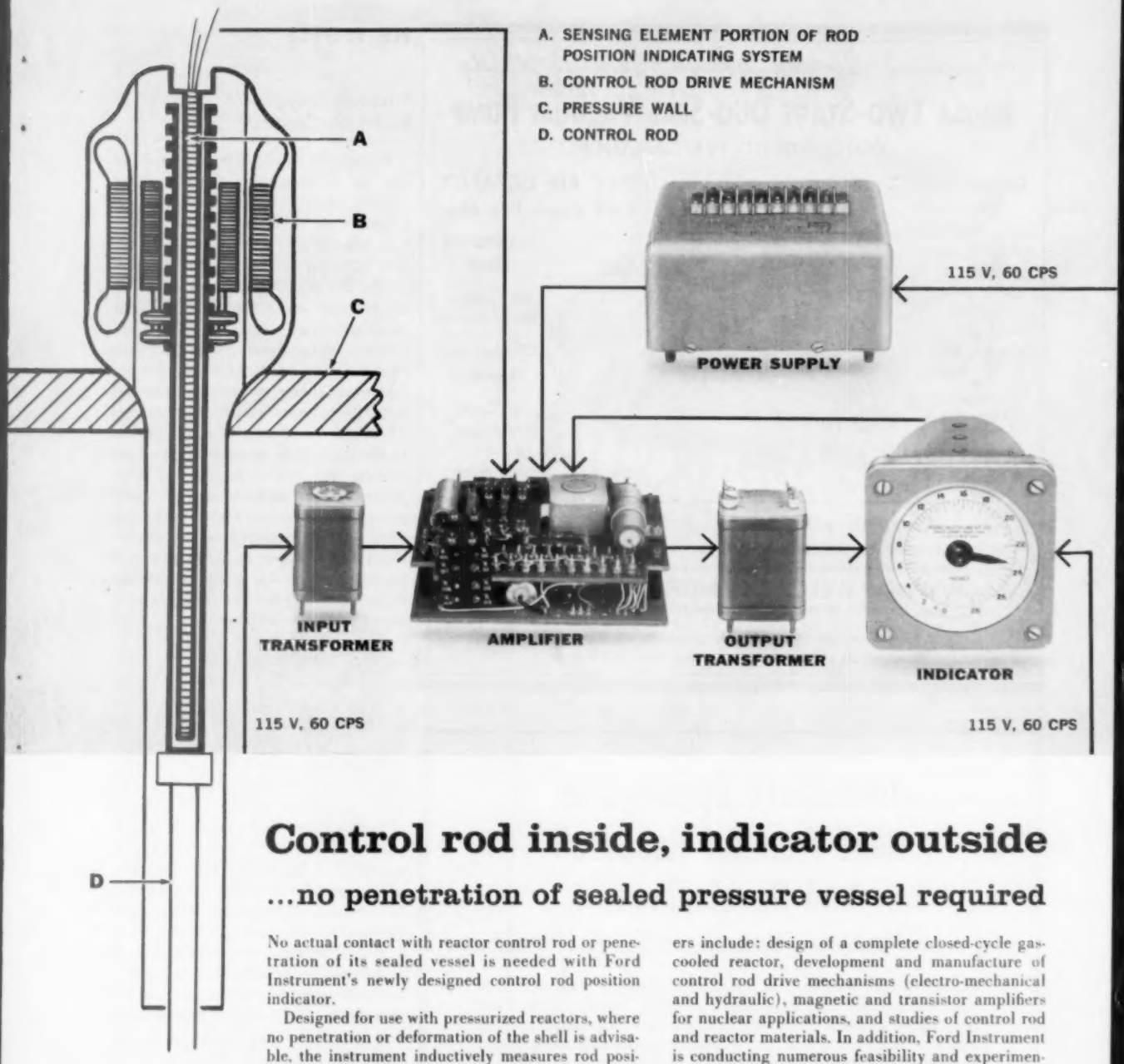
Thorium-uranium (10 wt%) alloy samples have been partially decontaminated using a salt-bed process, as reported by A. G. Buyers, J. Chilton and W. E. McKee of Atomics International. The method consists of induction-melting the alloy supported by a vertical column of compacted calcium fluoride. The molten metal then melts the surrounding salt and passes by gravity down through the salt column.

Melting periods of 3–28 min and 1–6¼-in.-long calcium fluoride columns have removed 35–98% of the cerium, strontium, rare earths and cesium; 70–80% of the tellurium was removed. Zirconium, ruthenium, protactinium and uranium were not appreciably extracted.

Thorium losses amounted to 1–12%. Efforts to eliminate this loss have not been successful. It is probable that a metal skin freezes into the salt due to a large temperature gradient. This might be reduced by preheating the salt bed.

The salt-metal system presumably does not reach equilibrium with regard to fission-product and fissionable-element distribution. However, near-equilibrium concentrations of impurity fluorides can be extracted by sufficiently long salt columns.

Other applications of salt-bed processing are indicated. These include fundamental studies requiring pure systems, recovery of valuable materials such as plutonium, metal purification and the use of refractory columns in drossing research.



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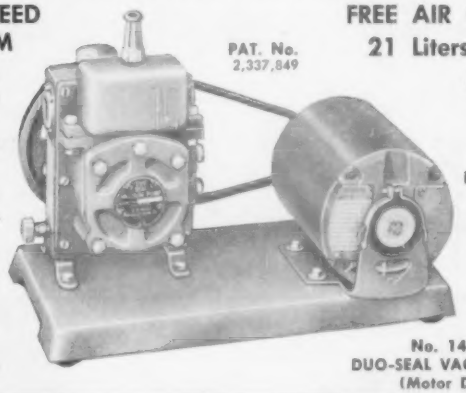

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NE NOTES

This article starts on page 104

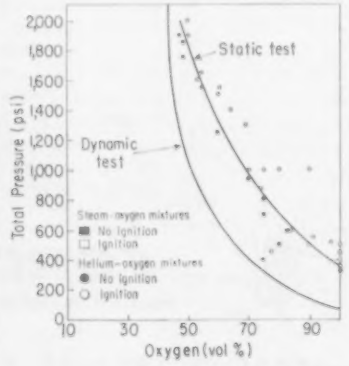
Titanium-Oxygen Reactions Studied

Failures of titanium parts tested for use in Homogeneous Reactor Test (HRT) at ORNL have revealed the existence of an intensive, short-duration chemical reaction with oxygen. The titanium had partly melted while in contact with hot aqueous solutions of uranium salts under an oxygen sur-pressure.

Preliminary results suggested that such reactions occurred when a freshly formed titanium surface was exposed to oxygen under sufficient pressures. Thus, when a titanium rod was broken in tension in the presence of oxygen at 350 psi and room temperature, autoignition of the metal occurred and the sample was completely consumed. No such reaction occurred in water saturated with oxygen at 2,000 psig and at temperatures up to 300° C; steam-oxygen mixtures did react with titanium under certain conditions.

The limits for the autoignition of massive shapes of titanium (as opposed to powdered or spongy titanium) have now been determined (see curve) for steam-oxygen and helium-oxygen mixtures in the range of 40–100% oxygen and pressures up to 2,000 psi. Steam-oxygen and helium-oxygen mixtures gave equivalent results. The effects of surface-to-volume ratios and of temperature up to 300° C were found to be negligible. Rapid and turbulent flow of the gases in dynamic tests resulted in a pronounced lowering of the ignition limits.

It is postulated that autoignition of metals can occur only when the rate of heat liberation by the oxidation of the metal exceeds the rate of heat dissipation, when enough heat is liberated to melt the surface of the metal, and



when the metal and its oxides are mutually soluble. Otherwise, a solid oxide scale is formed which slows down any subsequent oxidation.—F. E. Littman, F. M. Church, E. M. Kinderman, Stanford Research Institute, Menlo Park, Calif.

Scanning the Literature

(All of the following reports can be purchased from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.)

UO_2 thermal conductivity. In-pile measurements of the thermal conductivity of sintered UO_2 rods in a helium atmosphere have been made for centerline temperatures of 750°–1,100° F. No change in conductivity was observed during the irradiation period (0.7×10^{20} nvt). The Westinghouse report recommends 0.85 Btu/hr-ft-° F for the mean "effective" thermal conductivity of a He-filled UO_2 fuel rod with 0.0035-in. as-assembled annular clearance between rod and cladding. (WAPD-200).

Reactor theory vs. experiment. Two-group and multigroup calculations of the critical mass of two clean-geometry configurations of the BSR have been checked with critical experiments by Oak Ridge. Calculations using either the 30-group 9-region "Eyewash" code or a modified version (2-group 3-region) of the 3G3R code were both able to predict the critical mass within 2% of the measured value for the favorable geometric conditions considered. (ORNL-2499).

New pile oscillator tested. New design cycles specimen and standard through annular ion chamber in non-sensitive flux region allowing good cross-section measurements without large reactivity cycle. (BMI-1265).

Boron reduces neutron activation. The activity after irradiation of ⅛-in. stainless-steel samples was reduced by a factor of three with the addition of 1% of B^{10}; 3% B^{10} gave a factor of 10 reduction. (GE-ANP APEX-292).

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Effective Cross Sections for Thermal Spectra

By C. H. WESTCOTT
Atomic Energy of Canada Limited, Chalk River, Ontario

Adequate measurements of the slow-neutron cross sections are now generally available for the principal fissionable isotopes and the important neutron poisons. Thus it is possible to calculate the effective cross sections of these elements for reactor neutron spectra. In many instances, however, the cross sections are complicated functions of energy (not $1/v$) so that this becomes a tedious job requiring numerical analysis. The effective cross sections have been computed in this way at Chalk River Laboratories (*1*) for a number of such elements. Cross section values were obtained for Maxwellian neutron spectra (with and without an epithermal $1/E$ component) at temperatures from 20° C to 760° C. Results for Sm, Gd, U^{235} and the isotopes of Pu are given in Figs. 1 and 2. The effective cross sections are given in the form $\hat{\sigma} = \sigma_{2,200}\ (g + rs)$ where $\sigma_{2,200}$ is the monoenergetic-2200 m/sec cross section. The factor g, like the f-factor of BNL 325 (*2*), relates the effective cross section for a pure Maxwellian spectrum to $\sigma_{2,200}$, while s, which depends on the resonance integral, describes the contribution of the dE/E tail. The ratio r defines the proportion of epithermal neutrons in the reactor spectrum; more exactly, 1.01 r is the fraction of the total neutron density that is in the dE/E tail. (In NRX, for example, r varies from about 0.03 in the moderator to 0.07 in the fuel.) The dE/E tail begins at a lower limit of 5 kT.

The reaction rate is then the product of $\hat{\sigma}$ with the "2,200-m/sec flux," where the "2,200-m/sec flux" is defined as the total neutron density multiplied by 2,200 m/sec. For a $1/v$-law detector we have the simple result $\hat{\sigma} = \sigma_{2,200}$.

The basic cross section data was taken from BNL 325 (Second Edition) (*3*) for all cases. For fissile isotopes small changes were made when necessary to give a closer fit to the measured η-variation with energy. Analytical

Summary of Effective Cross Section Definitions*

Definition	*Reaction Rate*
$\hat{\sigma}(kT) \equiv g(kT)\sigma_{2200}$	$nv_0\sigma(kT)$
(where σ_{2200} is the monoenergetic cross section at 2,200 m/sec and $v_0 = 2{,}200$ m/sec)	
$\bar{\sigma}(kT) \equiv \overline{\sigma v}(kT)/\bar{v}(kT)$	$n\bar{v}(kT)\bar{\sigma}(kT)$
(where $\overline{\sigma v}$ and $\bar{v}$ are averages over the Maxwellian distribution; $\bar{v} = (4/\pi)^{1/2}(2kT/m)^{1/2}$	
$\sigma_{eff}(kT) \equiv f(kT)\sigma(kT)$	$nv(kT)\sigma_{eff}(kT)$
(where $\sigma(kT)$ and $v(kT)$ are the monoenergetic neutron cross section and velocity at neutron energy $E = kT$)	

* For a Maxwellian neutron distribution of temperature kT.

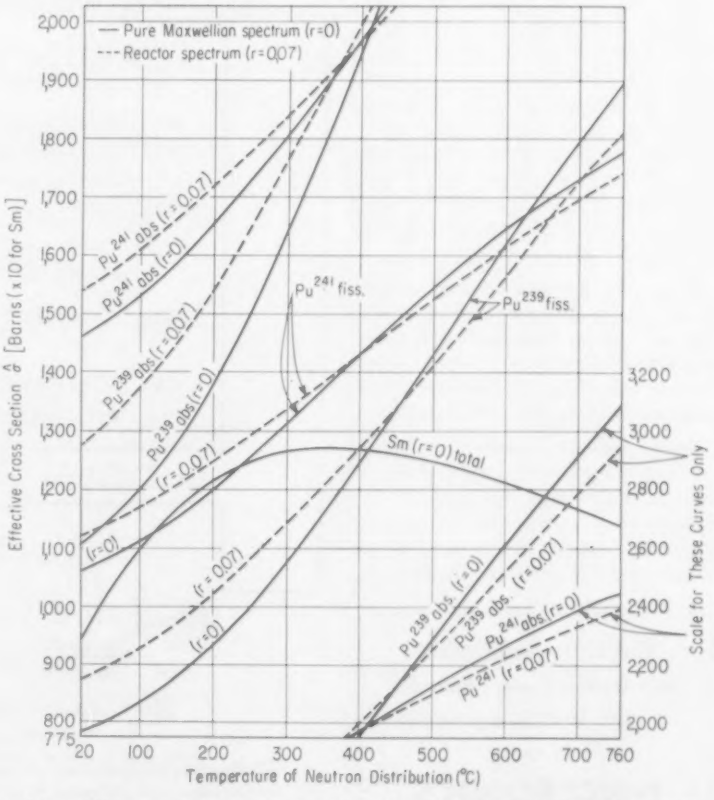

FIG. 1. Effective neutron cross section $\hat{\sigma}$ as a function of neutron distribution temperature for Sm and isotopes of Pu. Absorption curves for fissionable nuclides give total absorption

Sorting Out Cross-Section Definitions

Besides the effective cross section definition $\hat{\sigma}$ used here, the table lists two other definitions in common use.

For a pure Maxwellian spectrum $N(v,kT)$ the effective cross section $\bar{\sigma}$ can be defined from

$$\bar{\sigma} = \frac{\overline{\sigma v}}{\bar{v}} = \frac{\int_0^\infty \sigma v N dv}{\int_0^\infty v N dv}$$

The integral for $\bar{v}$ can be evaluated to give $\bar{v} = (4/\pi)^{1/2}(2kT/m)^{1/2}$. In terms of $\bar{\sigma}$ the reaction rate is $n\bar{v}\bar{\sigma}$ instead of $nv_0\hat{\sigma}$ as used for $\hat{\sigma}$. For reactor spectra containing an epithermal component, $\bar{v}$ is no longer easily given, so that $\hat{\sigma}$ is to be preferred to $\bar{\sigma}$. For a Maxwellian spectrum $\bar{\sigma} = \hat{\sigma}(\pi T_0/4T)^{1/2}$, where $T_0 = \frac{1}{2}mv_0^2$.

The third definition is given by Hughes and Harvey (*2*) as $\sigma_{eff}(kT) = f(kT)\sigma(kT)$, where f is plotted in the old BNL-325 (*2*), $\sigma(kT)$ is the monoenergetic cross section at the energy corresponding to kT and σ_{eff} is the effective cross section for a Maxwellian distribution. The reaction rate is given by $nv\sigma_{eff}$ where v is the monoenergetic neutron velocity at energy kT. For pure Maxwellian spectra $\sigma_{eff} = \hat{\sigma}(T_0/T)^{1/2}$. The g used in defining $\hat{\sigma}$ differs from the f used in defining σ_{eff}; in fact (again for a Maxwellian distribution), $f = [\sigma_{2200}/\sigma(kT)]g$. Thus g is equal to f only at $T = (T_0/T)^{1/2}/T_0$, where $\sigma_{2,200} = \sigma(kT)$. The g-factor has the advantage that it can be used without having to refer to the $\sigma(E)$ curve again for every new temperature. Also σ_{eff} is not defined for spectra having epithermal components. The use of effective cross sections of the $\hat{\sigma}$ type has been agreed on by the U. K. and Canadian groups and has been accepted with some limitations by the Tripartite Nuclear Cross Sections Committee. In the latest version of BNL 325 (*3*) Hughes and Schwartz recommend the use of g rather than f.

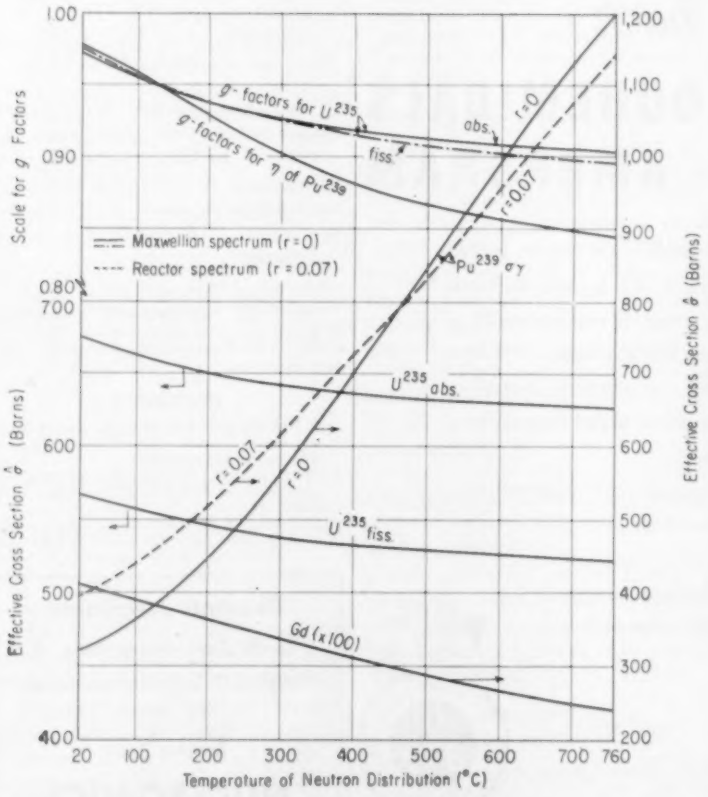

FIG. 2. Effective neutron cross sections vs. neutron distribution temperature for Gd and U^{235}. Also included are n-γ cross section for Pu^{239}, g factors for U^{235} and g factor for η of Pu^{239}. Latter is defined by $\eta(T) = g\eta_{2200}$

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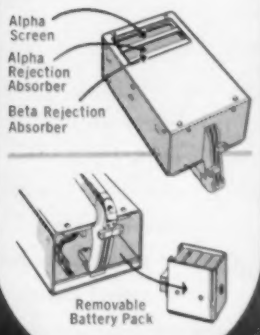

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This article starts on page 108

expressions based on a synthesized set of resonance parameters were developed that fit the experimental points to within 0.25% or better up to 0.12 ev. The spread of the experimental points about the curves was always much greater than the errors between the analytical expressions and the curves drawn by Brookhaven. These expressions were used in integrating over the Maxwellian distributions to find the effective cross sections.

The g- and s-factors can be used to predict cadmium ratios when the detector used has no resonance near the cadmium cutoff, and conversely to deduce the epithermal ratio parameter r of a reactor spectrum from measured cadmium ratios. For example, for a $1/v$-detector (for which by definition $g \equiv 1$ and $s \equiv 0$) the cadmium ratio, using a 0.040 in. Cd foil in a normally incident neutron beam, for example,* is just $1.994\,(T_0/T)^{1/2}/r$ where $T_0 = 293.6°$ K and T is the temperature of the neutrons in the Maxwellian distribution. For a detector of nonzero s but $1/v$ behavior near and below the cadmium cutoff, the cadmium ratio is

$$\frac{1+rs}{r}\left[\frac{1}{1.994}\left(\frac{T}{T}\right)^{1/2}+s\right]^{-1}$$

These values, like the effective-cross-section tables in the compilation (*1*), apply only to thin detectors in that self-shielding effects are not included—these depend on details of the geometry and cannot be included in a general compilation.

* See C. H. Westcott, 1958 Geneva Conference Paper 202 for numerical values for other Cd thicknesses and isotropically incident neutrons.

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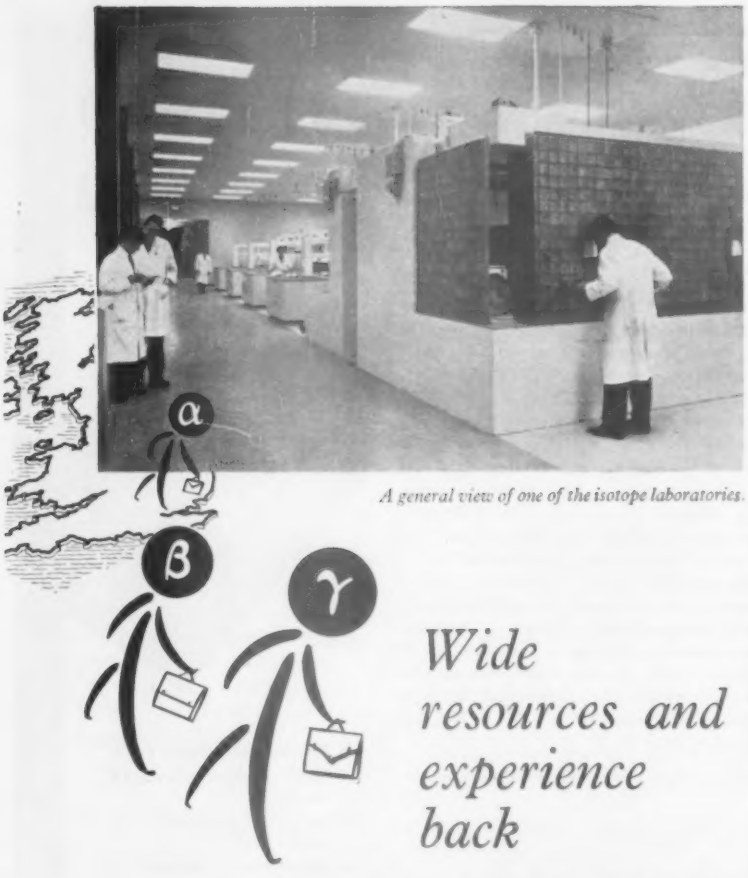

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TABLE 1—Specific Activities and Relative Abundances of U Isotopes (*2*, *3*)

Isotope	*Specific activity* ($\mu c/\mu g$)	*Isotopic abundance* (*fraction*)
U^{234}	6.18×10^{-3}	5.5×10^{-5}
U^{235}	2.14×10^{-6}	7.2×10^{-3}
U^{238}	3.34×10^{-7}	0.9927
U(natural)	6.86×10^{-7}	

Permissible Weight Concentrations for Enriched Uranium

By CHARLES A. PELLETIER
*Astra, Inc., Milford, Connecticut**

Processing natural uranium produces an airborne contamination level which is doubled when the same equipment is used to process an equal weight of ~2% enriched uranium. For example, if extruding a 300-lb billet of natural uranium produces an air contamination of 2.5×10^{-11} μc/ml, then 5.0×10^{-11} μc/ml can be expected from a 300-lb billet of 2% enriched uranium.

Yet on an activity basis, the maximum permissible concentration (MPC) of natural and enriched uranium is the same. The reason is that U^{234}, with its relatively high specific activity (SA), contributes greatly to the total SA of natural uranium. For example, for natural uranium in a 40-hr week, the MPC in air is 5×10^{-11} μc/ml (*1*), and the maximum permissible *weight* concentration (MPWC) is 7.28×10^{-6} μgm/ml. The MPWC is calculated from the equation

$$\frac{\text{MPC}}{\text{SA}} = \text{MPWC}$$

where MPC is given in μc/ml, MPWC in μgm/ml, and SA in $\mu c/\mu gm$. Both SA and the natural abundance of uranium isotopes are shown in Table 1.

To calculate the SA for various degrees of enrichment, we assumed that the ratio of U^{234} enrichment to the U^{235} enrichment remains constant during the enriching process. This assumption seems valid at low enrichments because the ideal separation factor (α) for the separation of U^{234} and U^{235} is only about 0.13% higher than that for the separation of U^{235} and U^{238}. At higher enrichments, however, more separation stages are required, so the 0.13% difference would probably cause the U^{234} content to increase significantly faster. Although U^{234} contributes about 50% of natural uranium's total activity, it contributes 75% of the activity of 2% enriched uranium and 90% of the activity of 10% enriched uranium; yet the assumption of a constant U^{234}/U^{235} ratio still seems valid for guidance in health considerations (*4*).

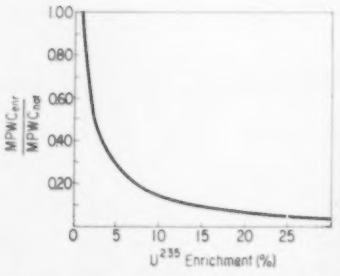

FIG. 1. Allowable weight concentration (relative to that of natural U) vs U^{235} enrichment. Note sharp decline in allowable concentration with even slight enrichment

Figure 1 plots values of enriched vs natural uranium MPWC as a function of U^{235} enrichment. Note the rapid decrease in allowable weight concentration as enrichment increases from natural to 5%. From a health standpoint, this means that much more care must be taken when handling even slightly enriched uranium.

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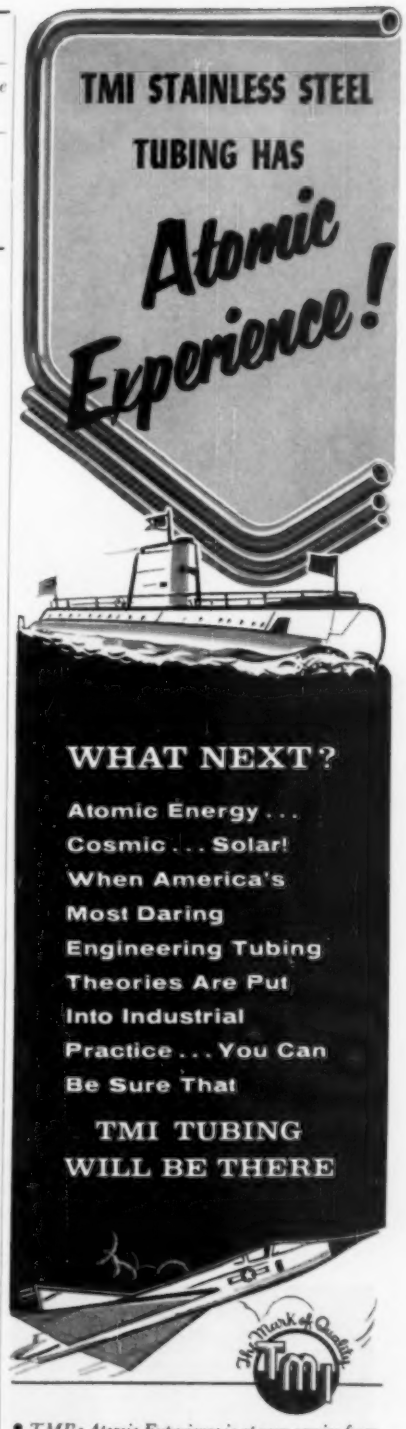
* PRESENT ADDRESS: Bethlehem Steel Co., Bethlehem, Pa.



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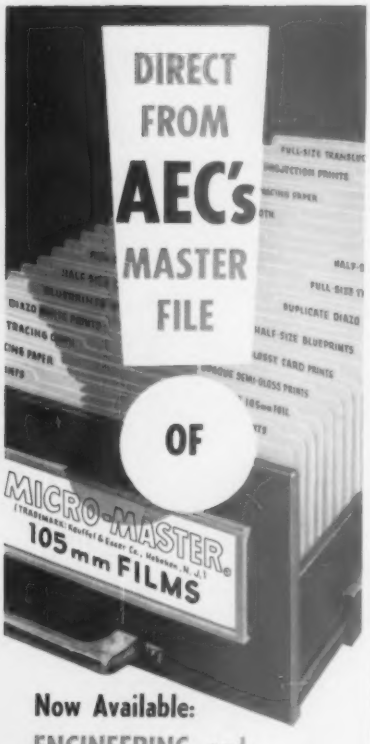

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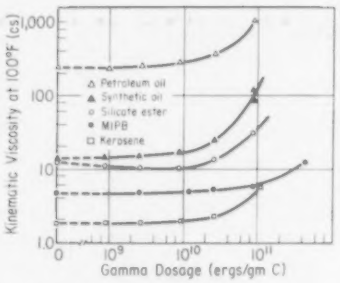


FIG. 1. Change in viscosity

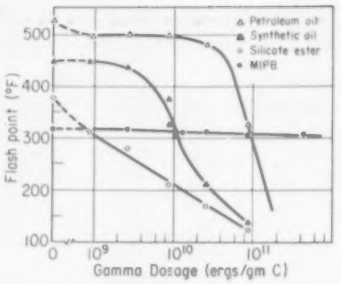


FIG. 2. Change in flash point

Effects of Gamma Radiation On Organic Fluids and Lubricants

By WILLIAM L. R. RICE
Wright Air Development Center
Wright-Patterson Air Force Base
Dayton, Ohio

Irradiations of static samples of lubricants and other organic materials, were conducted at ambient temperatures in the spent-fuel-element canal of the Materials Testing Reactor and at Hanford. Dosages from the two sources are reported in roentgens, but, in accordance with standard Air Force practice, the roentgen values were converted to the carbon standard (87.1 ergs per gram of carbon per roentgen). Dosages are not corrected for gamma attenuation. It has been estimated that the actual dosage in the MTR canal is roughly 85% of the given value and that at the Hanford facility is about 70% of the given value.

The following fluids were irradiated and tested: (a) a refined petroleum oil such as is used in aircraft reciprocating (piston) engines; (b) a diester-based aircraft-instrument lubricating oil; (c) a polymer-thickened silicate ester high-temperature hydraulic fluid; (d) an alkyl aromatic fluid, monoisopropylbiphenyl (MIPB); (e) a paraffinic kerosene (Special JP-5 from Eastern United States crude).

The effects of gamma radiation on the fluids were in certain instances quite marked. Figure 1 illustrates the change in kinematic viscosity at 100° F with irradiation. Up to about 10^9 ergs/gm C, there is, generally, a very small decrease in viscosity. Above 10^{10} ergs/gm C, the viscosity increases rapidly. For dosage levels above 10^{11} ergs/gm C, all but the most stable organic liquids solidify. For polymer thickened blends, such as the silicate ester hydraulic fluid, the viscosity in the lower ranges drops more markedly. A MIL-O-5606 hydraulic fluid showed a decrease of over 50% in viscosity after exposure to about 10^{10} ergs/gm C. It is believed that the thickener degrades greatly at lower dosages to cause the marked drop in viscosity. For higher exposure levels, the polymerization of the base fluid overrides, and the typical viscosity increase predominates.

Because a decrease in flash point is related to the presence of small amounts of contaminants (or, in this case, degradation products), change in flash point gives a rough measure of the relative stability of the various fluids to the gamma radiation. Flash-point changes are shown in Fig. 2. The petroleum oil shows only minor change up to about 10^{10} ergs/gm C, but above that dosage the flash point falls off quite rapidly. The diester fluid begins to display a drop in flash as low as 2×10^9 ergs/gm C, and the silicate ester fluid shows change at exposures

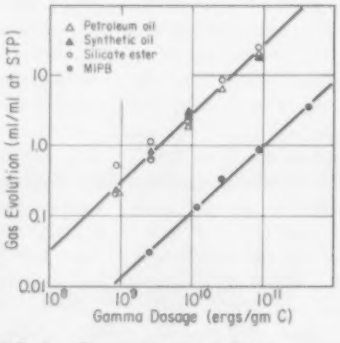


FIG. 3. Change in gas evolution

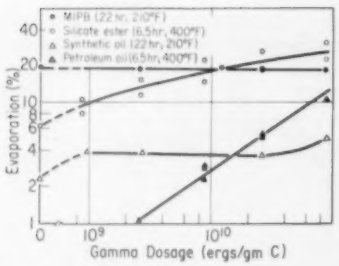


FIG. 4. Change in evaporation

below 10^9 ergs/gm C. The MIPB had practically constant flash point up to the highest exposure.

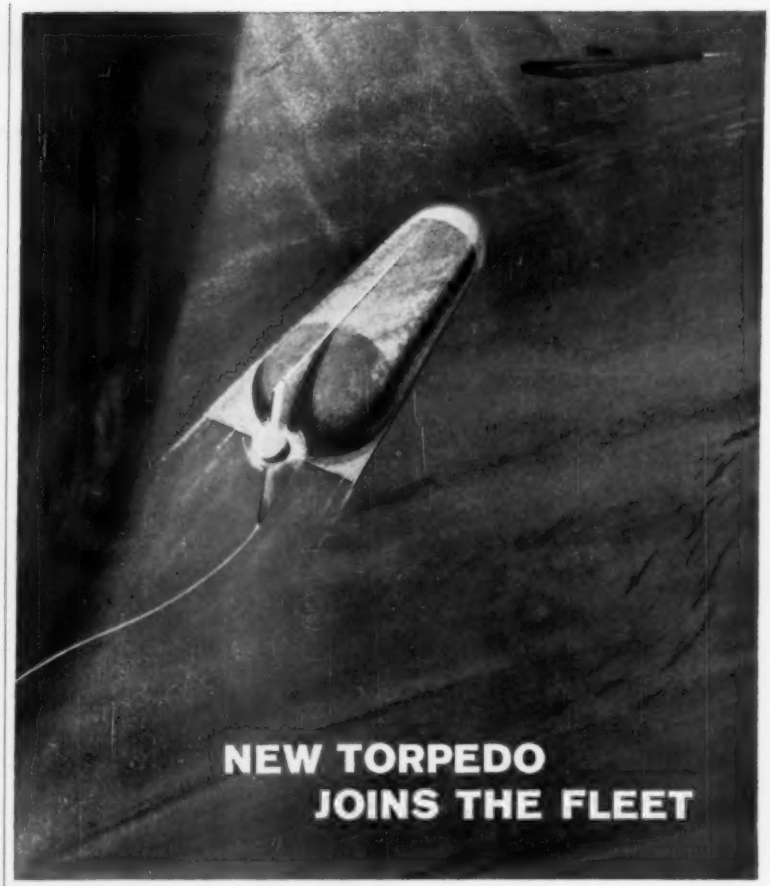
Gas evolution is common to all organic materials exposed to radiation. Figure 3 shows the relative susceptibility of the fluids to gassing during irradiation. Although the values are not too precise, being calculated from the canister pressure and gas volume, there appears to be a definite relationship between gassing and dosage level. The data indicates that this relationship is of a power-function type. The slope of the line has been observed to be generally less than unity, indicating proportionally less gas evolution at the higher dosage levels.

The evaporation test gives another indication of the formation of more volatile fragments during irradiation. Figure 4 shows the change in evaporation of the test fluids. Only the MIPB fluid did not display greater evaporation with increasing dosage.

Operating experience with irradiation loops shows that results markedly different from those predicted on the basis of static irradiations can be obtained. For example, thermal stability of jet fuels (as measured in standard loops that determine time to cause filter plugging) is seriously changed at radiation levels at which changes in the usual physical and chemical properties are not appreciable. Thus, it would seem that it is not possible to predict thermal stability changes without actual in-pile evaluation. Changes in such properties as viscosity are apparently not sufficient to allow correlation with expected over-all performance. It must be strongly emphasized, therefore, that studies such as this are but preliminary to the final evaluation of end-item useability. The next step is the in-pile evaluation of the more promising materials.

* * *

The author wishes to express his appreciation to Lt. Robert H. Johnson and Lt. William R. Daniels for conducting the irradiations.



VITRO'S weapon systems capability is dramatically demonstrated in the new Mark 39, a wire-guided torpedo which the U. S. Navy has just added to our growing arsenal of underwater weapons.

Spider-like, the torpedo pays out a wire as it drives through the water. Over this wire combat crews send electrical signals that guide it to its target, regardless of course changes or other evasive actions. Swimming deep, Mark 39 leaves no telltale wake, generates no pulsations for detection, relentlessly closes on its target regardless of defensive maneuvers.

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Polymer Degradation—Wide-Range Dosimeter

By PAUL Y. FENG
Armour Research Foundation, Chicago, Illinois

Polymer degradation can be the basis of a good wide-range dosimeter. Figure 1 shows data plotted from observations with the flow-type viscosimeter of Fig. 2. It confirms a simple theory that indicates that the curve of Fig. 1 should be a straight line.

Some polymers are degraded readily by ionizing radiation when they are dissolved in organic liquids. An example is polystyrene. Degradation occurs if radicals are produced copiously during radiolysis as they are in halogenated hydrocarbons (*1*). The nature of such degradations has been studied with X- and gamma rays (*2*, *3*). Examination of experimental results reveals that the extent of degradation can be related directly to dose and other parameters such as initial molecular weight and concentration of the solution.

Theory

It has been found experimentally that, as a first approximation, the number of polymer bonds cleaved in a polymer solution is independent of both molecular weight and polymer concentration, but increases linearly with dose. Therefore the relationship among initial and final average molecular weights and radiation dose is

$$\frac{M_f}{M_o} = \frac{N_o}{N_o + PR}$$

M_f and M_o are final and initial average molecular weights, respectively, N_o is the initial number of polymer molecules per unit weight of solution, P is the number of polymer bonds cleaved per unit dose, and R is total radiation dose.

On the other hand, average molecular weight is related to the intrinsic viscosity of a polymer η_i by $\eta_i = KM^\alpha$, where K and α are constants for specific systems (*4*). Intrinsic viscosity is defined as the limit of the ratio of specific viscosity to concentration as concentration is allowed to approach zero. That is

$$\eta_i = \lim_{C \to o} \frac{(t/t_o - 1)}{C}$$

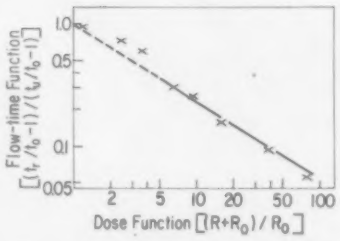

FIG. 1. Log-log plot of flow time function against dose function confirms theory that result should be a straight line. R_ϕ was 1.4×10^4 rads

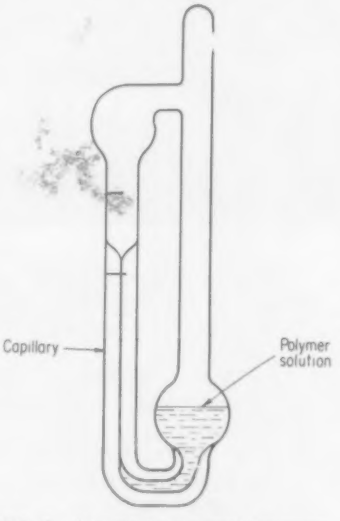

FIG. 2. Viscodosimeter used for measurements contains aerated solution of polystyrene in carbon tetrachloride. Over-all length is 7½ in. and capillary bore is ½ mm

where t_o is a flow time for the solvent in a flow-type viscosimeter and t is the corresponding flow time for the solution.

We have therefore

$$\eta_{i,o} = KM_o^\alpha$$

$$\eta_{i,f} = KM_f^\alpha = K\left(\frac{M_oN_o}{N_o + PR}\right)^\alpha$$

$$= \frac{\eta_{i,o}N_o^\alpha}{(N_o + PR)^\alpha}$$

A log-log plot of $\eta_{i,f}$ or $\eta_{i,f}/\eta_{i,o}$ against $N_o + PR$ should, therefore, produce a straight line. This treatment represents a considerably simplified model of the actual system, but it serves to illustrate the principle of the polymer-degradation dosimeter. A more rigorous treatment based on a statistical analysis and random degradation gives an essentially analogous result and suggests that the proposed dosimetry system should be useful over perhaps four decades of dose.

Experimental Confirmation

An additional fact makes the proposed dosimeter even more attractive from the viewpoint of practical application. If concentration remains constant, η_i becomes approximately proportional to $(t/t_o - 1)$. It follows that if t_r is the flow time for the solution at dose r and t_u is the flow time at zero dose (u = undosed), a log-log plot of $(t_r/t_o - 1)/(t_u/t_o - 1)$ against dose should be approximately linear. Figure 1 is a test of this relationship. Figure 2 shows the simple sealed viscodosimeter used in the experiments. The polymer solution was an aerated solution of polystyrene in carbon tetrachloride.

Useful Range

In general a given polymer dosimeter system is expected to be useful for radiation doses from 0.05 to 100 N_o/P. Depending on the composition of the system, N_o/P can range from 10^2 to 10^5 rads (*3*). On this basis, it can be expected that the useful range of the proposed system will be as broad as 10^2–10^8 rads. Such dosimeters would find use in measurements of large and small doses, particularly in situations in which radiation intensities are not constant. Further developments are required to perfect the system. They will be reported later.

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3. P. Y. Feng. Abstracts of papers presented at 2nd Winter Meeting, American Nuclear Society (New York City, 1957) p. 47
4. See, for example, P. Flory, "Polymer Chemistry" (Cornell University Press, 1953)

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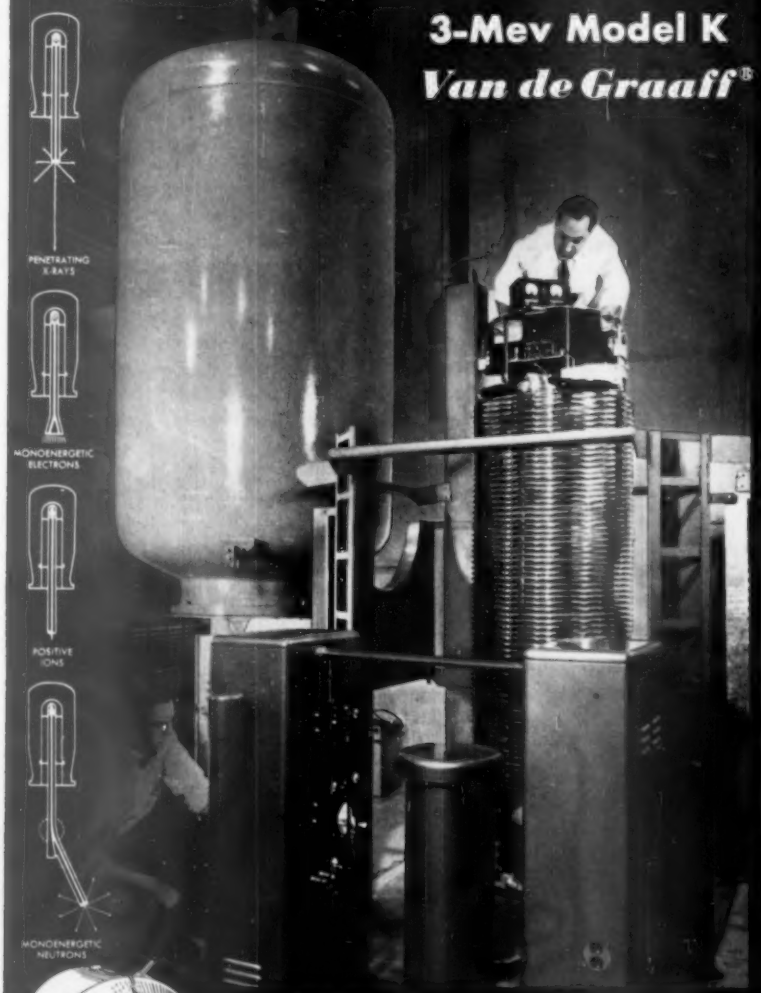

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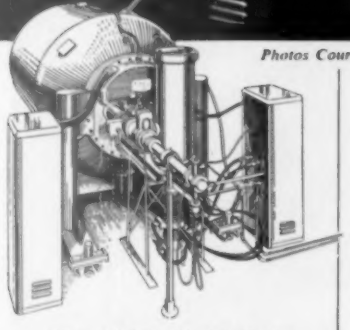

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11

APPLIED RADIATION

Sewage Treatment— Another Suggestion We discussed the problem of sewage irradiation recently (NU, July '58, p. 106) saying mainly that no one had yet found an economical way to do it. The item inspired further thought on the subject from Carlos Bell, Associate Professor of Civil Engineering at Northwestern University. In the following letter he suggests (1) using heat and radiation for drying and sterilizing sewage sludge and (2) irradiating conventionally treated sewage in an attempt to improve the microorganisms by genetic mutation:

DEAR SIR:

Your recent comments (Sewage Irradiation—Is It Economical?) on the use of a reactor for sewage sterilization are on a subject of much interest to us sanitary engineers. This is despite such a process being, to put it mildly, an uneconomical undertaking at present. The main practical problem in sewage treatment apparently will remain reduction of the biochemical oxygen demand—not sterilization. Sterilization should not significantly change the B.O.D., a term used for the measured estimate of the amount of dissolved oxygen required by biological organisms aerobically to oxidize the available organic material in the sewage. At saturation, rivers have approximately 8 mg of oxygen per liter of liquid. Sewage has a B.O.D. (5 days, 20° C) of around 200 mg/liter.

One application that seems less impractical at present is the use of low-grade reactor-produced heat in the drying of fresh activated sludge for disposal. Possibly the gamma flux could sterilize the dry sludge so that it could have safer use as a soil conditioner.

Suggested experiment. If anyone ever builds such a reactor sewage-sterilization or sewage-sludge-drying device, may I suggest an experiment? The activated sludge of the sewage-treatment plant would be continuously exposed during recirculation to a nonsterilizing, but highly mutating gamma source, with the objective of making the sewage treatment process itself more efficient. There have been cases in other fields in which pure strains of organisms have been genetically modified. This has been done in a batch process by ionizing radiation to produce increases in proportions of desired biochemical end products. Perhaps the activated sludge treatment rate of sewage is held at its present level by a single organism in the treatment chain. Perhaps treatment is essentially on an individual-organism basis. Isn't it just possible, because of the short generation time

GENEVA FISHERMAN. This is the picture Donald E. Hull of California Research Corp. presented at last month's Geneva Conference. He presented it as a part of paper P/817 entitled, "Flow Measurement by the Total Count Method." The lure at the end of the line is a radiation detector. The catch is the total count, which goes into the scalar sitting on the bank and serving as a creel. The stopwatch on the counter is not to remind him to go home; it simply makes the total count into counts per minute. His companion, fishing for total count on the opposite bank reminds him to go home

of most sewage treatment organisms, that treatment could be genetically improved? By the same approach, sewage treatment by trickling filtration and anaerobic digestion, which also are huge survival-of-the-fittest competitions in colonies of microorganisms, might be improved. Naturally if the experiments were successful, culture transfers to other plants should not be difficult.

Admittedly, the chance for eventual success by this scheme might be much less than that proposed in your article. But, as our country alone spends many megabucks per year on sewage treatment, might not my suggestion be a worthwhile straw at which to grab?

—Carlos G. Bell
Northwestern University
Evanston, Illinois

Radiotracers Control Remote Booster Pumps

Automatic-control problems in pipeline booster pumps are being handled with the help of radio-tracers. They are used to provide signals to tell the pumps to clear themselves of one fluid before the next one comes along. The system permits completely automatic operation of remotely placed pumps that would otherwise demand two-man attention.

Remotely located booster pumps in petroleum lines are arranged to go on automatically and pump the fluid in the line around a check valve whenever line pressure indicates that pumping is needed to maintain throughput. One problem is that when they turn themselves off, the pumps and the lines leading to and from them are filled with fluid. When the pumps go on again, a different fluid may be going through the line, and mixing two fluids is undesirable.

The Salt Lake Pipe Line Co. uses the 1.2 mc of Sb^{124} that marks an interface to clear the pump of its fluid before the next one comes along. G-M counters upstream from the pumps turn them on. A time-delay relay keeps them operating for 12 min, and then they go off again unless the pressure signal indicates that they are still needed.

Since the radionuclide is already there, the only additional expense is $4,000 for detection and telemetering equipment. To accomplish the task manually would require two men and a sampling vehicle at an annual cost of $14,000 and a capital investment in housing of $40,000.

The method and application are covered by patents.

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RADIOACTIVE WASTE TREATMENT AND DISPOSAL

Disposal of the radioactive waste products of a nuclear reactor presents a serious problem. Radioactivity waste differs from ordinary chemical or sanitary refuse in that it cannot be destroyed chemically. Therefore, planning for treatment and storage of wastes must be undertaken in the early stages of reactor design. Under a prime contract with the Atomic Energy Commission, NSEC scientists recently completed a comprehensive survey of all current practices as well as planned techniques for the disposal of highly radioactive waste materials. *Much of our report is still classified. But NSEC is ready to put its findings to work for those who are planning reactors for power or testing purposes. Write to Mr. Eli I. Goodman of our Engineering Department about your reactor plans. Or ask for our new bulletin which outlines the factors to be considered.*

WATER TRACING WITH HYDROGEN ISOTOPES

Ever been confronted with leakage in a system of underground water pipes? This tracing problem has been solved by NSEC scientists using tritium, the radioactive hydrogen isotope. Both tritium and deuterium, a non-radioactive hydrogen isotope, are used in tracking water flow. Often the path of rainwater, underground streams or reservoirs must be traced. NSEC experts conduct assays of the tritium and deuterium content of the water. They measure tritium with a sensitivity of 10^{-5} microcuries per milliliter. The deuterium content in water is determined using the density-gradient method. Both these hydrogen Isotopes are also used to discover the origin of ground water, thus aiding in water conservation. *NSEC assay services assist in other ways, too, including the biological tracing of organic matter for medical and industrial studies. Interested? Phone us in Pittsburgh at Homestead 2-4000.*

TESTING FOR SUSTAINED RELEASE OF DRUGS

A number of pharmaceutical companies are now working to develop a single dosage form of a drug which will be effective over a long period of time: from 12 to 24 hours. The drug, whether capsule, compound or complex, must have a gradual, uniform absorption rate. Its effect must be continuous.

There are many advantages to a prolonged acting drug over a drug which must be taken every few hours. But one of the development problems is *in vivo* testing. How fast is the release rate? Are the peaks and valleys on the absorption curve too pronounced? What is the blood concentration of the drug?

NSEC personnel are now performing such studies for drug firms. Through radioactive tracers, we are able to measure much lower levels and with greater specificity than is possible under conventional colorimetric or fluorimetric methods. *Our specialized procedures are particularly applicable when a very small amount of a drug is to be given. Contact our Biology & Medicine Department for more information.*

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In the development and operation of nuclear reactors, it is necessary to know the neutron flux at various points in the reactor. NSEC offers a dosimetry service to determine neutron fluxes—to measure thermal, epithermal, and fast neutrons. NSEC provides the dosimeters, the required analytical services, and a report on flux data. Special fission dosimeters are also supplied, for direct measurement of burn-up occurring in fissionable material during irradiation. NSEC designs and develops techniques for difficult or unusual dosimetery problems. *It's possible to measure neutron flux from the highest now available down to 1 neutron per square centimeter per second. For additional information about NSEC's dosimetry services, contact Dr. R. C. Koch of our Chemistry Department.*

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BOOKS

The Chemistry of the Actinide Elements

By JOSEPH J. KATZ and GLENN T. SEABORG (John Wiley & Sons, New York, Methuen and Co., London, 1958, xv + 508 pages, $14.00).

Reviewed by J. C. HINDMAN, Argonne National Laboratory, Lemont, Ill.

According to the authors' foreword, this volume is intended to give a comprehensive and unified treatment of the chemistry of the actinide elements for both the nuclear technologist and the inorganic and physical chemist. It is the reviewer's opinion that the authors have succeeded admirably in this undertaking.

The volume is divided into eleven chapters. The first nine are devoted to a detailed description of each of the elements from actinium through curium. The tenth chapter summarizes the information on the transcurium elements. The last chapter is a critical survey of the comparative chemistry and a correlation of the properties of the elements as a group.

The separate chapters are divided into sections starting with a brief historical outline of the element. This is followed by sections on the properties of the known isotopes, the occurrence and methods of isolation of the element, properties of the metal and its compounds, and, finally, a survey of the solution chemistry.

The book is extremely well written. An enormous amount of information has been summarized with the emphasis placed on the quantitative aspects of the chemistry. The treatment throughout is critical. Full advantage has been taken of the authors' access to the latest available data. As a consequence, the volume is very up to date. The referencing is extensive.

This volume is a must for all those engaged in work in the chemical aspects of the atomic energy field. It should also be valuable as a reference volume for students and investigators in inorganic chemistry.

Mésure et Detection des Rayonnements Nucléaires

By J. SHARPE and D. TAYLOR (Dunod, Paris, 1958, xi + 321 pages, $8.50).

Reviewed by N. BENEZER-KOLLER, Columbia University, New York, N. Y.

This book is a translation of two recent Methuen monographs, "Nuclear Radiation Detectors" by J. Sharpe and "The Measurements of Radioisotopes" by D. Taylor. These authors presented clearly a wealth of material in two short volumes. It is now very convenient to have under one cover information covering both the methods and tools of nuclear detection as well as an explanation of the physical processes involved.

The material of the two texts was reorganized by the translater, J. Chatelet, into three parts.

In the first, the general methods for the use of standard detectors such as ionization chambers and G-M counters are described. The most interesting part in the preliminary chapters is the detailed discussion of counting statistics, geometrical effects, shielding problems, corrections due to self-absorption in the sources, detector dead-time effects and the source lifetime correction.

The second part deals mainly with the physical phenomena of detection. The introduction treats the interaction of neutrons, charged particles and electromagnetic radiation with matter. A very instructive chapter (rarely found elsewhere in similar texts) follows explaining theoretically the scintillation processes in organic and inorganic crystals and an equally good analysis of ionizing effects in gaseous detectors. Also described are the properties and main characteristics of available photomultiplier tubes and associated electronics.

The third part deals with the actual assembling and functioning of ionization chambers and G-M, proportional and scintillation counters. The most recent advances in nuclear instrumentation are also briefly sketched (such as multichannel analyzers with magnetic-core memory and transistor amplifiers). The last chapter deals with health precautions necessary in a radiation laboratory.

The book thus provides an excellent survey of the widely used detectors for low-energy radiations. It is somewhat unfortunate that, due to the juxtaposition of two books on very closely related subjects, there are various repetitions, and the material is not as well organized as might be expected, especially the first and third parts.

The index is quite incomplete. The bibliography, though, appropriately refers not only to experimental papers but also to theoretical treatises where the fundamental interactions are studied. The tables and curves that would make this book useful as a laboratory manual are unfortunately few.

The value of this book is not, however, in its being a manual, but in its clear and complete explanation of the physical phenomena by which nuclear particles interact with matter and are detected. The book deals with very basic problems and basic instrumentation and thus does not run the danger of becoming outdated in a short time.

Fundamental Constants of Physics

By E. R. COHEN, K. M. CROWE and J. W. M. DUMOND (Interscience Publishers, New York, 1957, xii + 287 pages, $7.50).

Reviewed by VAL. L. FITCH, Palmer Physics Laboratory, Princeton University, Princeton, N. J.

It is a pleasure to review a book written by individuals so well qualified to discuss the subject. A common complaint about the rapidly expanding literature in physics is that the individuals who are making the contributions and are most familiar with the subject are not the ones who are taking the time to write the books and review articles. The criticism does not apply here. Dr. Cohen and Prof. DuMond have concerned themselves for a long time with the best values for the "classical atomic constants of physics." Dr. Crowe is an experienced hand in high-energy physics and has contributed an up-to-date section on the constants associated with mesons and strange particles.

This book is not merely a tabulation of the constants of physics with an attendant bibliography filling the majority of the pages. As the authors say in their introduction, they have three objectives: "(1) a brief introductory outline of the system of physical units and the standards set up to maintain them; (2) a sketch of the history of the progress of our knowledge of the general physical constants with special emphasis on the atomic constants, giving brief descriptions of both the earlier methods employed and the more modern methods now in use for this evaluation; (3) a detailed study as of 1955 of the status of our knowledge of the physical constants and a least-squares evaluation to obtain the best compromise values consistent with the entire body of present knowledge.

These final output results are tabulated at the end of this text." It is the opinion of this reviewer that, in view of the final product, these objectives are very modest.

With regard to the first objective, most readers will find the discussion completely adequate. The authors have substantially exceeded their objective by including a useful chapter on the properties of atoms, mesons, nucleons and hyperons. While the field of strange particles is advancing so fast that anything published is automatically out of date by the time it reaches the reader, the review of all of the literature up to the time of publication is helpful to all individuals working in this field.

The second objective was achieved with a very fascinating history of the atomic constants. The style reminded this reader of Whittaker's highly readable "History of the Theories of Aether and Electricity." In telling this story, the authors have performed the same service for this aspect of experimental physics as Whittaker did for theoretical physics.

Whether the authors have succeeded in attaining their third objective perhaps only R. T. Birge is qualified to say. The data are reviewed in the tradition of that distinguished physicist and the book is a tribute to him. The methods of weighing the various data and handling the associated errors are all clearly delineated and should be studied by all students of experimental physics. The physical constants listed throughout the book and the tabulation of the atomic constants at the end of the book ensures it daily usefulness to the practicing physicist. This reviewer has not utilized his reviewer's license to search out obscure typographical errors. This book is so enormously useful, it is likely that an error in any number in the book will be propagated very quickly throughout the literature. Indeed, the error will be propagated so quickly that it will undoubtedly be most convenient to retain the error and redefine the standard to which the number refers.

There is perhaps one omission. The discussion of interaction constants was limited to the gravitational and electromagnetic. This reader wondered if a discussion of the constants relating to the strong and weak interactions would be premature. Knowledge of a constant of nature to only one significant figure does not keep that constant from being any less fundamental.

BOOKS RECEIVED

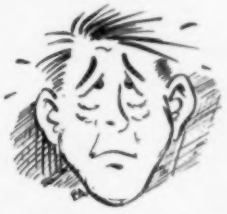
Nuclear Engineering Monographs, 1–3, W. K. Mansfield, editor (Temple Press, London, 1958). **1—Elementary Nuclear Physics,** W. K. Mansfield (viii + 60 pages, $1.56). This volume is aimed at college students and technical men who need a broad understanding of some of the more important concepts in the nuclear field. Topics range from Bohr's hydrogen atom through neutron physics and scintillation counters. **2—Nuclear Reactor Theory,** J. J. Syrett (viii + 80 pages, $1.85). This outline of reactor design physics is more technical than the first volume. It includes explanations of critical size, neutron behavior in reactor lattices and reactor stability. Emphasis is on graphite-moderated natural-uranium reactors. **3—Reactor Heat Transfer,** W. B. Hall (viii + 68 pages, $1.56). This is a 3-section paper on convective heat transfer and its reactor design implications, aimed at engineers or students with some knowledge of thermodynamics.

Castilla's Spanish and English Technical Dictionary, 2 vols. (Philosophical Library, New York, 1958, 2,748 pages, $45). A comprehensive and detailed work; Vol. 1 is English-Spanish, Vol. 2 is Spanish-English. Only engineering fields are covered; the physical, chemical, and biological sciences are excluded, except those words which, in the opinions of the editors, "are of importance to engineers and technologists."

Physics and Philosophy, by Werner Heisenberg (Harper & Brothers, New York, 1958, xv + 206 pages, $4). This is a nonmathematical discussion of quantum mechanics, relativity, and the ways in which they differ in their viewpoints of a contingent universe. Heisenberg defends the idea that "atoms or the elementary particles themselves . . . form a world of potentialities or possibilities rather than one of things or facts."

The Atomic Age and Our Biological Future, by H. V. Brøndsted (Philosophical Library, New York, 1957, xiv + 80 pages, $2.75.) This popularization of the biological—and, primarily, the genetic—effect of radiation paints an admittedly gloomy picture. The author concludes that future hydrogen bomb tests are unjustifiable from the point of view of future generations.

ELIMINATE CLOTHING-DECONTAMINATION PROBLEMS



The health physicist daily pondered how should contaminated clothes be laundered

The job was done at lower rate, when he used Interstate

AEC LICENSED NATIONWIDE COVERAGE

Interstate's rental program provides the garments of your choice—maintenance and decontamination, all at a cost comparable to or less than your present cost.

Eliminate costly investment in protective garments and laundry equipment. Purchase of your existing equipment can be arranged.

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295 PARKER STREET
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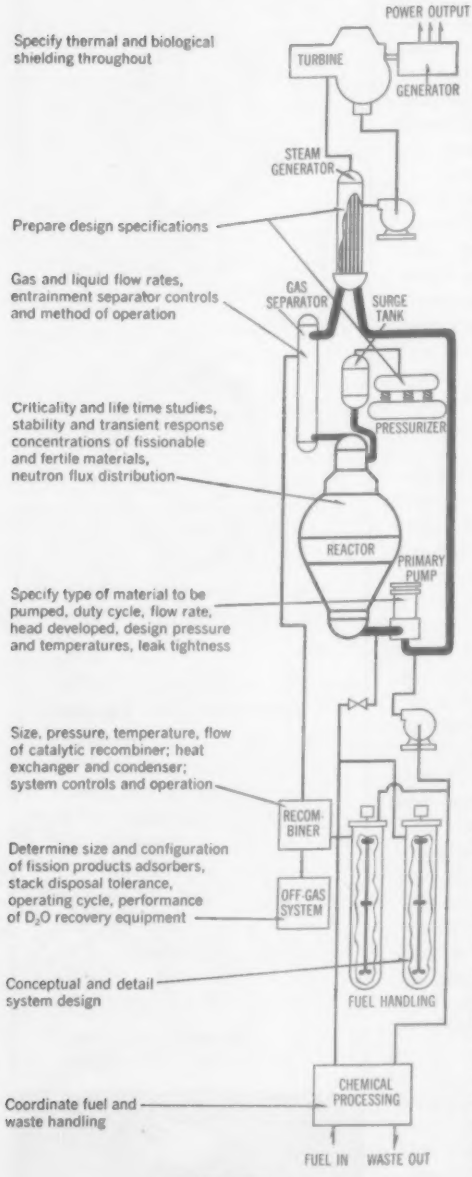
NUCLEAR ENGINEERS

WESTINGHOUSE COMMERCIAL ATOMIC POWER COMES OF AGE

Where would you work on an atomic power plant?


POWER OUTPUT
Specify thermal and biological shielding throughout
TURBINE
GENERATOR
STEAM GENERATOR
Prepare design specifications
Gas and liquid flow rates, entrainment separator controls and method of operation
GAS SEPARATOR
SURGE TANK
PRESSURIZER
Criticality and life time studies, stability and transient response concentrations of fissionable and fertile materials, neutron flux distribution
REACTOR
PRIMARY PUMP
Specify type of material to be pumped, duty cycle, flow rate, head developed, design pressure and temperatures, leak tightness
Size, pressure, temperature, flow of catalytic recombiner; heat exchanger and condenser; system controls and operation
RECOMBINER
Determine size and configuration of fission products adsorbers, stack disposal tolerance, operating cycle, performance of D_2O recovery equipment
OFF-GAS SYSTEM
Conceptual and detail system design
FUEL HANDLING
Coordinate fuel and waste handling
CHEMICAL PROCESSING
FUEL IN
WASTE OUT

This diagram shows the main parts of the world's first homogeneous power plant being developed by Westinghouse Atomic Power Department in conjunction with Pennsylvania Power and Light Company . . . and just where you would work. This pioneering plant, unlike the heterogeneous reactor, will use a liquid or "slurry" nuclear fuel, capable of continuous reprocessing.

5 Commercial Atomic Power Programs Now Under Way

1. **A 150-megawatt homogeneous reactor for Pennsylvania Power & Light Co.**
2. **The first industry-owned testing reactor for nuclear-materials study (Owned by Westinghouse).**
3. **A 134-megawatt reactor for Yankee Atomic Electric Co.**
4. **A 134-megawatt atomic plant for Edison-Volta, Italy.**
5. **An 11.5-megawatt pressurized water reactor for Belgium.**

Also research, analysis, and development of advanced reactor types . . . and more programs, national and international, are coming in.

Immediate openings in the Pittsburgh area for: Nuclear Engineers. Metallurgists. Physicists. Ceramists. Mechanical Engineers. Chemists. Chemical Engineers. Instrumentation & Control Engineers. Atomic experience desirable but not necessary . . . we're not dependent on government subsidy . . . opportunities for advanced study on company fellowships.

Send your résumé to: C. S. Southard, Westinghouse Atomic Power Department, Box 355, Dept. #C-4, Pittsburgh 30, Pa.

Westinghouse

FIRST IN ATOMIC POWER

LETTERS

Datum Correction

DEAR SIR:

In reference to NUCLEONICS Data Sheet No. 23 (NU, March '58, p. 88), I believe that the σ_a quoted for Gd (element 64) is erroneously stated as 3,900 barns. From other sources it would appear that the proper value is 39,000 barns [when corrected by the "not $1/v$" factor of 0.85 quoted by Prof. Murray in "Nuclear Reactor Physics" (cf. p. 32)].

—SHERWOOD B. MENKES
Associate Professor of Mech. Eng.
The City College of New York
New York, N. Y.

Control-Rod Drive

DEAR SIR:

The article "Control Rod Drives," by Kann and Harrer (NU, May '58, p. 84), provides a fairly complete coverage of pressurized drive mechanisms presently existing. However, conspicuous by its absence is the AMF Atomics high-pressure control-rod actuator, which is actually a composite of the desirable features of those actuators described in the subject article.

As described in a paper presented at the Nuclear Engineering and Science Conference at Chicago in March of 1958 ("High Pressure Control Rod Actuator," paper No. 197), the AMF actuator is a combination of components proven in existing reactors and packaged to be economically attractive. The actuator has been fabricated and successfully tested utilizing proprietary funds. To the best of my knowledge, this is the only attempt at such an approach. As a proprietary item, its design must be flexible so that it can be adapted to various reactors. Thus the components utilized can be arranged for top mounting, although the tested model is mounted on the reactor bottom.

The actuator features a pressure-breakdown, collected-leakage rotary seal. Scramming is not accomplished "through the seal"; therefore, the scrammed parts have a lower inertia value. The latch utilized for the "internal" scram also allows the scram spring to be held "cocked," thus the scram-spring compression load is segregated from the normal driving load, and the scram force is independent of control-rod position.

Seal packages are available for pressurized-water reactors or, as a less expensive unit, for the lower-pressure boiling-water reactors. The stroke, load, rod speed, position-indicating system, etc., can be varied to suit the reactor specifications under consideration without resorting to costly and lengthy development programs. Another advantage of the AMF design is that it requires no special auxiliary equipment such as valves, pumps, motors and power supplies.

The drive package containing the drive motor, speed reducer, position-indicating system, limit switches and clutch can be selected from many combinations of commercially available equipment. This, of course, is one of the advantages of a control-rod actuator utilizing a seal.

—Charles Linnert
Engineering Department
Nuclear Equipment Section
AMF Atomics
Greenwich, Connecticut

Attenuation Misinterpreted

Dear Sir:

We should like to point out some necessary corrections in Data Sheet No. 25, "Attenuation of γ-rays from an Infinite Plane" (NU, June '58, p. 63).

First, there are two typographical errors:

Eq. 2 should read

$$\frac{1}{2}\left[\frac{e^{-b}}{2} - E_1(b)\right]$$

and in the example $\phi/\phi_0 = 0.1$ rather than -0.1.

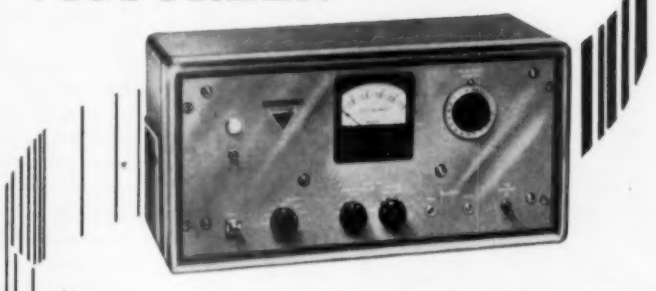
More importantly, however, it has become apparent that many readers did not appreciate that we were using attenuation in a different sense than is usual. The nomogram given provides the approximate flux observed on the far side of a shield covering an infinite plane isotropic source of *unit source strength per unit area*.

Thus it is not attenuation in the usual sense that is plotted; one way to appreciate this is to recognize that since the flux would be infinite in the absence of absorber between plane source and detector, it is not possible to speak of an attenuation factor in the usual sense.

Perhaps it would have been better to define our basic quantity as ϕ/S_A.

—M. G. Chasanov
and M. Shatzkes
International Business Machines Corp.
Owego, New York

VICTOREEN



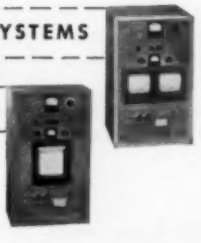
New Victoreen Model 727 Logarithmic Count Rate Meter built to ORNL SPECIFICATION Q14548.

Logarithmic Count Rate Meter

for

MONITORING SYSTEMS

GAMMA RAY SPECTROMETRY



Based on the Cooke-Yarborough circuit and of latest ORNL design, the Victoreen Model 727 Logarithmic Count Rate Meter is a wide-range, five-decade instrument for use with all types of radiation detectors. Incorporating a Schmidt trigger circuit for discrimination, the instrument covers, on a single scale, a range of from 10 to 1,000,000 counts per minute without mechanical switching as on linear type rate meters.

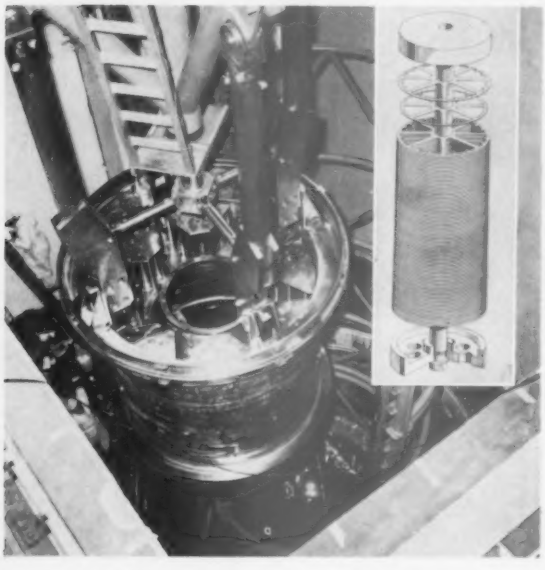
If your problem involves gamma monitoring with scintillation counter . . . beta-gamma monitoring with Geiger counter . . . gamma ray spectrometry—it will pay you to check these specifications:

Range: From 10 cpm to 1,000,000 cpm in 5 decades
Accuracy: ±2% over entire range. Better than 1% in vicinity of calibration point
Input Sensitivity: ±5 volt peak to peak minimum
Recorder Output: 0-10 millivolt
Calibration Check: Internal calibration source—six frequencies available: 360, 720, 1440, 3600, 7200 and 14,400 cpm
Pulse Height Discriminator: Variable from −50 to +100 volts
Drift: Less than 1% in 24 hours
Power Requirements: 115 volts, 60 cycles, 135 watts
Dimensions: Relay Rack Panel 8¾" x 19"
Shipping Weight: 60 pounds

AA-7942

The Victoreen Instrument Company
5800-10 Hough Avenue • Cleveland 3, Ohio
WORLD'S FIRST NUCLEAR COMPANY

Filters for Cleanup of Primary Coolant Systems



A filtering device to remove foreign matter present in the reactor system following fabrication is shown above being lowered into the Shippingport reactor vessel. Location of the filter was dictated by the need to clean up all four loops simultaneously at maximum system pressure, temperature and flow. The unit was also to act as a pressure-drop simulator. This would enable pumps, valves and instrumentation to be checked out during the precritical filtration cycle. The filter was designed around a basic edge-type filter cartridge (inset), the Super Auto-Klean, to provide positive removal of all particles larger than 0.005 in. (125 microns). In addition, some of the cartridges were sized to remove particles larger than 0.002 in. (50 microns). Because the system was closed and recirculating, it was anticipated that >99% of all particles larger than 50 microns would be removed. Forty cartridges arranged in eight banks of five were used. Each cartridge is 5.7 in. in diameter and consists of a series of major and minor discs (each 0.025 in. thick) keyed to, and supported by, a center spindle. Closure plates at either end of the spindle keep the discs tightly compressed. The degree of filtration is determined by the difference in diameter between the o.d. of the minor (or smaller) disc and the i.d. of the outer rim of the major (larger) disc. Particles or foreign material larger than the nominal difference in diameters are trapped on the o.d. of the minor discs, while larger particles are trapped on the o.d. of the major discs, thereby actually providing two-stage filtration in a single cartridge. Filtering water passes axially down the inside of the stack of discs and is discharged through orifice holes. During operation, flow rates up to 31.76×10^6 lb/hr of water were passed through the filter at temperatures ranging up to 527° F. The major portion of foreign material removed consisted of black iron oxide with particle sizes ranging from ~50 microns up to <300 microns. In addition, a small piece of cloth and a number of stainless steel slivers, including a small amount of weld spatter, were removed.—The Cuno Engineering Corp., Meriden, Conn.

Monitor-Ratemeter

Model 743 combination radiation alarm monitor and ratemeter provides continuous visual and audible indication of radioactivity levels with ranges of 0–600, 0–6,000, 0–60,000 cpm. Alarm range is continually adjustable to any point on any range. Input sensitivity is 0.25 v, accuracy ± 5% and time constant 5 sec. Power supply is continuously variable from 800–1500 v. Internal, 60-cycle test circuit is incorporated for calibration check.—The Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Solid-Film Lubricant

"Molytox Plus" is surface treatment grade of molybdenised lubricant produced by careful matching of particle sizes of solid content. It produces film that resists wear over 15 times as long as original Molytox and is also superior to existing varnish-held dispersions and molybdenised disulphide plating processes.—Rocol, Ltd., Rocol House, Swillington, Leeds, England.

Power Supply

Model 212 "Ultra Stable" high-voltage supply is continuously variable from 500–1,800 v. Stability is >0.01% per °C change in ambient temperature plus 0.01% for maximum change in line or load per day. Regulation is 2 mv (at 1,800 v d-c) per volt change in line over the range of 95–125 v. Output current is 5 ma maximum; impedance <2 ohm; recovery time <75 μsec; noise <0.0003% rms.—Radiation Instrument Development Laboratory, 5737 S. Halsted Street, Chicago 21, Ill.

Super-Alloy Tubing

Line comprising 16 different analyses is limited to heat-resistant alloys that will not rupture under stress load of 25,000 psi at 1,200° F during 1000-hr test period. Both seamless and Weldrawn (welded and drawn) tubing is furnished in size range of 0.012 to 1.125 in. o.d.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

Radioactive Waste Container

New 5-c Co^{60} waste container for sea disposal (above) is 14 in. high and meets ICC-SS requirements. Other containers for liquid or solid radio-

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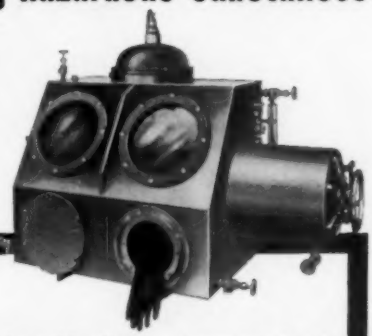
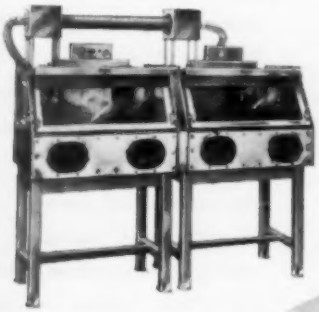
22 types of SAFETY ENCLOSURES for handling hazardous substances

VACUUM DRY BOX
for work in controlled atmosphere • sloping front • round autoclave-type air lock.

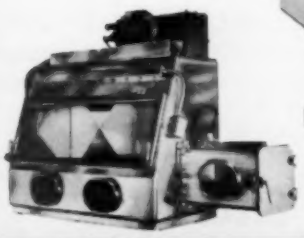


Safety is the first consideration in this newly-designed stainless steel laboratory equipment. These enclosures make it safer—and easier—for the technician to work with contaminants, micro-organisms, live viruses, infected animals, poisonous and radioactive substances. Stainless steel constructed with crevice-free surfaces, generously rounded corners, for easy cleaning and decontamination. Write for illustrated folder describing 22 different kinds of enclosures. S. BLICKMAN, INC., 7910 GREGORY AVENUE, WEEHAWKEN, N. J.



UNITIZED ENCLOSURES
Low in cost • Stainless steel • Modular construction adapts to many uses.

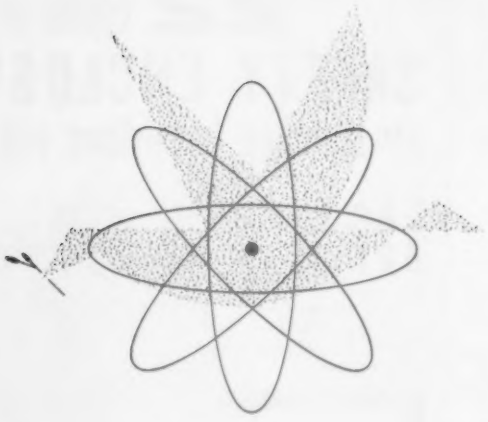
CALIFORNIA-TYPE FUME HOOD
For handling radioactive materials • dual-sided for double operation.



MICRO-BIOLOGICAL SAFETY CABINET
Back or top mounting of biological filter canister • air lock if wanted.

BLICKMAN SAFETY ENCLOSURES

Look for this symbol of quality Blickman-Built



performance for PEACE

More than sixty Los Alamos scientists were invited to Switzerland by the United Nations to participate in the 1958 International Conference on Peaceful Uses of Atomic Energy. Five major experimental devices, designed at Los Alamos, were set up at Geneva and exhibited in operation.

This international prestige of the Los Alamos Scientific Laboratory has been well earned by the members of its staff, an informal and creative community of scientists and engineers.

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active wastes are available. All are shipped complete with steel drum mounted on skid, instructions and all necessary labels.—Reliance, Inc., 1212 Adams Ave., Philadelphia, Pa.

Filament Transformer

Unit (above) is for 50-kv operation under oil. Secondaries are insulated from each other as well as from primary and core up to 50 kv d-c. Model shown is used for Eimac 250R rectifier tube, but different types are available for other kinds of rectifiers.—Del Electronics Corp., 521 Homestead Ave., Mount Vernon, N. Y.

Electrometer

Model E-100 general specifications are as follows: current range, 10^{-12}–10^{-3} amp full scale; line voltage, 105—125 v at 50–60 cps; accuracy, 3% on 10^{-3}–10^{-11} amp ranges and 5% on 10^{-12} amp range; drift stabilized to <2% per week on 10^{-11} and higher ranges; high stability from doubly regulated electrometer tube; 100-mv recorder output.—Gyra Electronics Corp., 518 N. Spring Ave., La Grange Park, Ill.

Filter Elements

Filter elements of type-316 stainless steel are available with ranges of 5–7, 7–10 and 10–13 microns. Body of type-303 stainless can be supplied with ⅛-, ¼-, ⅜- or ½-in. female pipe connections and is designed to permit replacement of filter element. Maximum operating pressure is 5,000 psi and temperature limits are 60–450° F.—Hoke, Inc., 136 S. Dean St., Englewood N. J.

Sapphire Windows

Window assemblies are available for high-temperature, high-vacuum applications. Synthetic sapphire parts are discs up to 3 in. in diameter and ¼ in. thick and tubes up to ½ in. in diameter and 2 in. long with bores of ¼ in. These are hermetically sealed to tubu-

lar metal members of kovar, nickel-iron, and platinum by silver-copper brazing alloy.—Ceramaseal, Inc., P. O. Box 25, New Lebanon Center, N. Y.

Radiation Counter

Rapid-response gamma-radiation counter has response rate of the order of 10 msec or better. It uses 2-in. diameter, 2-in. long, sodium-iodide crystal that produces over-all counting rate of 11,000 cps/mv/hr.—Stanley Aviation Corp., 2500 Dallas St., Denver 8, Colorado.

100-Channel Analyzer

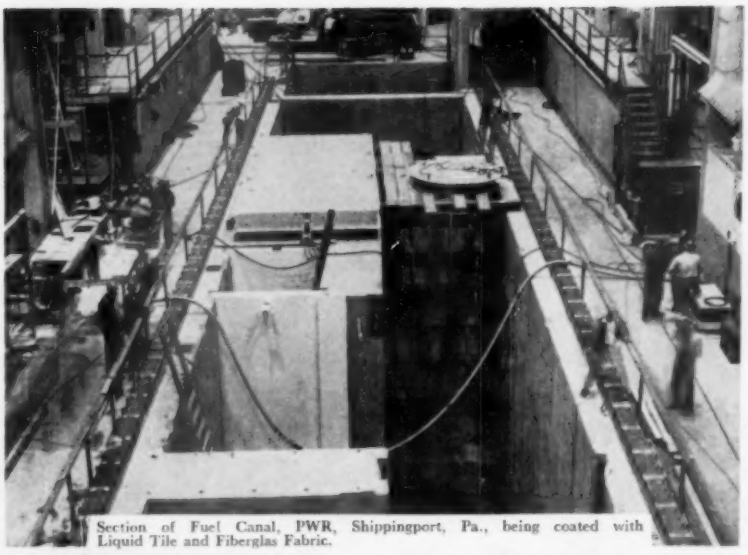
Model PHA-100-20 pulse-height analyzer consists essentially of 100-channel, analog-to-digital converter plus 20 channels of glow-transfer-tube storage capacity. Any 20-channel group can be selected for storage of data by means of single switch setting. Instrument contains all components necessary for complete scintillation spectrometer except phototube and crystal. Linearity is 0.5% and deadtime is 500 μsec.—Tullamore Electronics Laboratory, 6055 S. Ashland Ave., Chicago 36, Ill.

Radiochromatogram Scanner

Model RSC-5 (above) has automatic, windowless operation with following features: scanner drum can be rotated manually to locate peaks rapidly, entire scanning unit is enclosed in gas-filled chamber, radiochromatograms up to 56 cm can be scanned, maximum width of paper strip is 3.5 cm, cycle of chromatogram can be automatically repeated.—Atomic Accessories, Inc., 244-02 Jamaica Ave., Bellerose 26, N. Y.

Scintillation Crystals

CsI (Tl) crystals are nonhydroscopic, stable, have good linear response to heavy ionizing radiation, good pulse height, decay constant of 1.1 μsec, high



Section of Fuel Canal, PWR, Shippingport, Pa., being coated with Liquid Tile and Fiberglas Fabric.

10^9 R . . . without breakdown . . . decontaminated with soap and water

At Argonne National Laboratory, at Shippingport, and at Idaho Falls nuclear facilities, EVERSHIELD Process LIQUID TILE has proven its ability to solve the toughest atomic coating problems. It has received 10^9 R without breakdown, then has been decontaminated easily with soap and water.

100% SOLIDS COATING

Liquid Tile is a thermal setting plastic resin. Applied as a liquid, it cures by internal heat (it has no solvents) into a vitreous hard, totally unbroken surface in 1 to 4 hours. It is completely non-porous and corrosion resistant. It is therefore a highly efficient coating for areas where other coatings, and ceramic finishes, fail to give the desired performance.

APPLICATION

Liquid Tile may be applied by brush, spray or roller. It can be applied as thin as varnish, or heavy as whipped cream. Its versatility enables the applicator to coat almost unlimited types of surfaces. Even the coarsest cinder or slag block can be made 100% vapor proof with 2 coats. Stronger-than-steel laminations can be applied by integrating fiberglas fabric into the coating.

CHARACTERISTICS

ABRASION RESISTANCE: Sandblasting with #1 silica fails to remove it.

CHEMICAL RESISTANCE: Unaffected by most acids. Boiling in 5% H_2SO_4 and 5% NaOH produced no effect. Unaffected by intermittent exposure to extreme solvents through spillage, drainage and washing.

WATER RESISTANCE: 100% vapor/water proof, shown by submersion 15 years.

WEATHER RESISTANCE: 2400 hrs. (10 yr. equivalent) in Atlas Weatherometer produced no change.

LIFE: No known end to life of Liquid Tile.

EVERSHIELD LIQUID TILE INSTALLATIONS

EBWR—Argonne National Lab
PWR—Shippingport, Pa.
Fuels Technology Bldg.—Argonne National Lab
Expended Core Facility—NRTS, Idaho
Martin Company—Maryland
Test Reactor—Babcock & Wilcox, Va.
ERCO Plant, ACF Industries, Maryland
Union Carbide, Oak Ridge
Los Alamos Scientific Lab
Decontamination Bldg.—Argonne National Lab
Physics & Metallurgical Hot Lab—Argonne National Lab
Argonaut Training Reactor—Argonne National Lab

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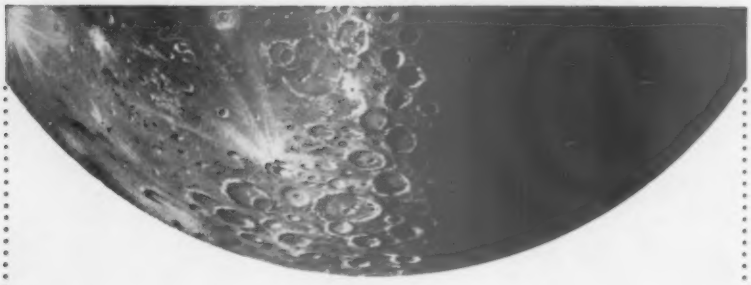

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This is an outstanding opportunity to join Rocketdyne in Air Force study and research activities directed toward a nuclear rocket engine.

You'll work with Dr. R. B. Dillaway, one of the nation's foremost nuclear propulsion scientists.

Please check the following list of positions now open in engine feasibility studies and preliminary design:

1. Senior Engineer Research or Engineering: Nuclear physicist, PhD. (or equivalent experience) for basic studies in the application of nuclear power to air vehicles.

2. Senior Engineer Research: Nuclear Engineer, M.S. degree or equivalent, with a background in unconventional powerplant design.

3. Research Engineer: B.S. degree in nuclear engineering. College work in general powerplant design.

4. Engineering Specialist or Senior Engineer Research: M.S. or equivalent, with a strong background in hydrodynamics and fluid mechanics to study basic relationships of propulsion equipment for air vehicles.

5. Senior Engineer Research or Engineering Specialist: PhD. desired with a background in nuclear energy, servo mechanism, controls or instrumentation. Should have preferably 4 years additional experience.

6. Senior Engineer Research: PhD. or M.S. degree with a background in heat transfer relating to gas or liquid cooled nuclear power plants, preferably of aircraft type.

7. Senior Structural Engineer or Stress Analyst: Several years experience in mechanical stress and structural analysis. M.S. or B.S. degree or equivalent.

Please direct your inquiry to Dr. R. B. Dillaway,
Nuclear Propulsion Group, Dept. 9
6633 Canoga Avenue, Canoga Park, California

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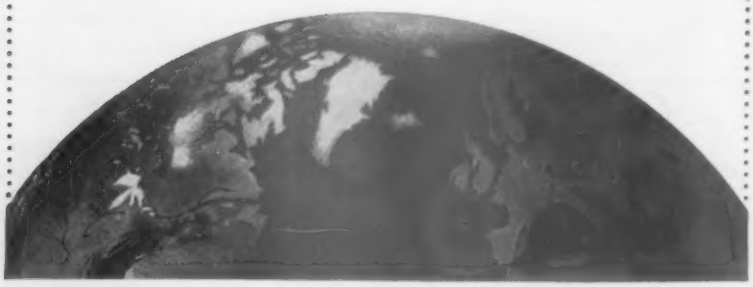
A DIVISION OF NORTH AMERICAN AVIATION, INC.

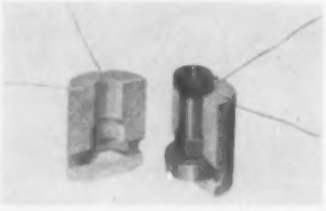
BUILDERS OF POWER FOR OUTER SPACE



integrated luminescent efficiency and large absorption coefficient for gamma rays. Crystals can be fabricated as thin as 0.005 in.—Isomet Corp., P. O. Box 341, Palisades Park, N. J.

20-Channel Time Analyzer

Model TA-20 is designed specifically for neutron-lifetime studies. Channel width is continuously variable from 10 μsec to 0.1 sec with a calibration accuracy of ±2%. Unit is provided with choice of single or dual inputs so that starting and storing functions can be separated. One pulse per channel per time cycle can be recorded. Outputs are provided for each channel and for total start pulses, total stored pulses and total time cycles.—Tullamore Electronics Laboratory, 6055 S. Asland Ave., Chicago 36, Ill.

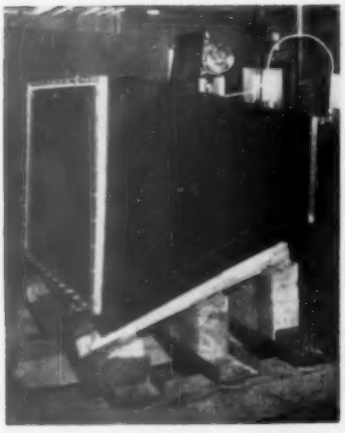


Heating Element

Thermoshell electric heating elements can be used to heat valve on line carrying high-temperature sodium (above) or organics. Heat is distributed uniformly over entire area with close contact between element and surface of pipe or valve. Resistor wires in element are properly spaced and remain permanently in position to prevent hot spots.—Cooley Electric Manufacturing Corp., 58 S. Shelby St., Indianapolis 7, Ind.

Scaler Converter

Model PCC 10A converts any scaler into proportional counter for measurement of radioactivity in prepared samples. Unit features transistorized built-in amplifier-discriminator. It detects alpha and beta activities of all energies; detects beta in the presence of alpha without absorbers and alpha in the presence of beta. Output pulse needs no amplification; goes directly into the scaling circuit for counting. Standard chamber accepts samples up to 2¼-in. diameter by 1/16 in.—Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.



Shielding Window

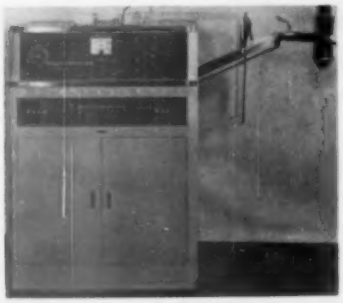
Radiation shielding window (above) features tapered housing, is 20% lighter than previous models, is made up of 3.3- or 6.2-density glass, 2–5 ft in thickness and weighs 2–10 tons. Normal viewing area is 3–4 sq ft.—Corning Glass Works, Corning, N. Y.

Radiography Unit

Cyclops cobalt-60 radiography unit provides facilities for radiographing heavy steel castings, weldments and other steel products up to 10 in. thick with 1% and 2% radiographic sensitivity. It can radiograph 6 in. of steel in 15 min., 5 in. in 6.0 min., 2 in. in 0.5 min., etc.—Picker X-Ray Corp., 25 S. Broadway, White Plains, N. Y.

Electrometer

Model 6000 Dynacon is dynamic condenser electrometer designed to accept and measure radioactive carbon-14, tritium, or sulfur-35 samples in the solid, liquid, and gas phases.—Nuclear-Chicago Corp., 229 W. Erie St., Chicago 10, Ill.



Scintillation Detector

SN-100 Scintiscanner (above) is scintillation gamma detector featuring changeable collimators. It is possible to work with two radioisotopes simul-

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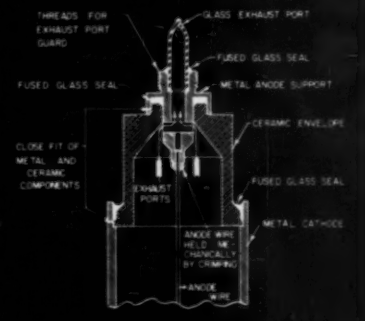

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taneously and to detect them individually. Activity can be read or recorded as rate or totaled by the binary scaler. Output totals from scaler can either be stored in registor or put on paper by solenoid printer. Printer follows detector on parallel plane, making plot on X-axis and space on Y-axis.—Reed-Curtis Nuclear Div., American Electronics, Inc., 9459 W. Jefferson Blvd., Culver City, Calif.

Radiation Analyzer

Model DZ46 gamma-ray spectrum recorder features automatic single or repetitive scan, front panel selection of five scanning speeds, front panel selection of scanning limits and automatic repetitive charting with no mirror image.—BJ Electronics Div., Borg-Warner Corp., 3300 Newport Blvd., Santa Ana, Calif.

Shielded Container

Model L-10 is storage container (above) for Ernst and other cervical uterine applicators with lead shield, 2-in. thick, mounted in cubical wood enclosure. Lead plug is used, and container is equipped with lid that can be padlocked. Container meets AEC requirements for any amount of cobalt-60 up to 125 mc or up to 165 mg of radium.—NRD Instrument Co., 9842 Manchester Rd., St. Louis 19, Mo.

Power Supply

Model 550 continuously variable d-c power supply is completely transistorized. Powered from 115 v a-c, characteristics include 3–45 v, 0–5 amp, output impedance 0.01 ohms and <8 mv ripple. It incorporates overload protection that can be preset and provides for remote sensing of voltage at load, floating output, and quality Phaostron meters.—Sila-Kon Eng'r Co., 605 Hoyt Ave., El Monte, Calif.

Spectrum Analyzer

Kicksorter incorporates form of Wilkinson system of pulse amplitude to digital conversion and 100-channel magnetic-core memory with digital binary capacity of 65,535 counts per channel. Dead time between pulses is 35–135 μsec, depending on pulse amplitude. Spectrum analyses can be obtained to equivalent of 1,000 channels within 30-v range, provided by means of channel width and bias controls. Circuit is 88% transistorized.—Bendix Aviation Corp., Cincinnati, Ohio.

Radiochemicals

EQ Paks are 50-μc quantities of radiocarbon compounds that are AEC license-exempt when up to 10 such Paks are held at one time. They have specific activity of 0.5–1 mc/millimole (approximately 10,000 dps/mg).—Tracerlab, Inc., 1601 Trapelo Rd., Waltham 54, Mass.

Canned-Motor Pumps

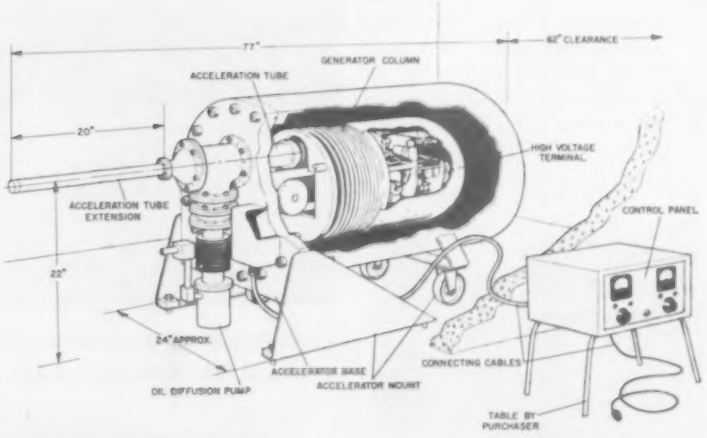
Positive-displacement canned-motor pumps are suited for high-temperature applications and offer metered volume from 1 gpm and 15 psi upward. Connections are either direct pump threaded or flanged (rigid or resilient) with either angular rubber cradle or rigid base mounting.—Reversa-Flo Canned Motor & Pump Co., P. O. Box 6657, Philadelphia 49, Pa.

Liquid-Metal Pumps

Vertical electrodynamic pump is for liquid metals at temperatures up to 1,600° F and pressures up to 250 psi. Pumps range in capacity from low rates of flow to several thousand gallons per minute.—Liquid Metals, Inc., P. O. Box 266, Westford, Mass.

Dosimeter

Personnel dosimeter (above) uses principle of charged spheres. Accuracy is ±20% under all conditions. It can be discharged and charged again as often as needed, and no external charging equipment is required. It is completely tamper-proof and cannot be discharged except by ionizing radiation.—Pacific Transducer Corp., 11836 W. Pico Blvd., Los Angeles 64, Calif.



New Pulsed Neutron Source

Model PN-250 is Van de Graaff particle accelerator (above) designed especially for pulsed neutron output. Compact positive-ion accelerator has energy rating of 0.25 Mev with ion current during pulse of 50 μa (nominal). Pulse length is 100 μsec, adjustable to pulse lengths in the 25–250 μsec range. Pulse rise and decay time is <5 μsec, with a pulse repetition rate of 400 pps (nominal) and synchronous with the alternator supplying ion-source power.—High Voltage Engineering Corp., Burlington, Mass.

Electronic Recorder

"Universal" recorder has following features: hinged chart plate; black indicator for 300-deg, 29-in. translucent scale; reservoir pens; transparent indicator support; hooded lights that illuminate chart, scale and integrator without glare; linear input that is recorded with accuracy to ±0.2% of scale span; square-law input accuracy up to ±0.25% of full-scale between 10% and 100% of span; full-scale pen travel of 4–5 sec. In addition, recorder also offers air check for oxygen-analyzer calibration and zero check for flow measurement at 20% of scale.—The Hays Corp., Michigan City, Ind.

High-Vacuum Pump

VacIon achieves clean vacuums in excess of 10^{-9} mm Hg. It ionizes and remove gas molecules with pumping speed of 10 liters/sec at 10^{-7} mm Hg. —Varian Associates, 611 Hansen Way, Palo Alto, Calif.

Kr^{85} in Rare Gases

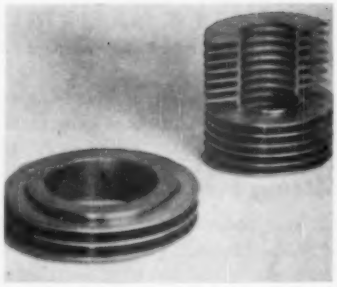
Guaranteed 99.995%-pure argon gas containing >50 ppm of impurities is available for all orders and refers to delivery state for all methods of delivery. Argon delivered in liquid form has >99.995% minimum purity, averaging <25 ppm of impurities and containing practically no moisture. Also available is radioactive krypton-85 in rare gas mixtures.—Linde Co. Div., Union Carbide Corp., 30 E. 42nd St., New York 17, N. Y.

Pulse-Height Selector

Model PA-3B single-channel, pulse-height selector with linear amplifier provides wide differential range with three modes of pulse-height selection: integral mode for counting all pulses above base line, 0-10-v window mode, and upper-limit mode that makes window control 0–100-v upper limit (for counting pulses between lower and upper limits).—Technical Measurement Corp., 140 State St., New Haven, Conn.

Scintillation Spectrometer

Multichannel scintillation spectrometer is stable, nonoverloading system with 120 channels taken 20 at a time. Scintillation detector is available with solid or well crystal. Gating provisions are made for coincidence or anticoincidence operation—Baird-Atomic, Inc., 33 University Rd., Cambridge 38, Mass.

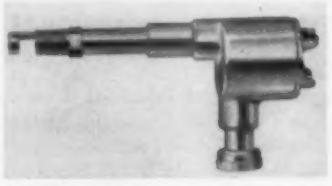


Heat-Exchanger Tubing

Integrally-finned tubing (above) for gas-cooled, nuclear-power-plant heat exchangers is fabricated by rolling series of equally-spaced fins up from tube walls. Now available in U. S. with following specifications: for low-carbon steel, fin height is $\frac{3}{16}$–$\frac{1}{2}$ in., 5 or 7 fins per in., $\frac{1}{16}$–$\frac{1}{4}$ in. tube-wall thickness; for Magnox, fin height is $\frac{3}{16}$–$\frac{5}{8}$ in., 5, 7 or 9 fins per in., 0.040–0.250 in. tube-wall thickness.—Wolverine Tube Div., Calumet & Hecla, Inc., 17200 Southfield Rd., Allen Park, Mich.

Radiography Service

Highly stressed castings and weldments are tested with million-volt Van de Graaff. Weldments of stainless steel, Monel, Inconel, in heavy sections as well as assemblies can be inspected.—Arnold Greene & Co., Inc., 122 Hampshire St., Cambridge 39, Mass.



Liquid-Level Sensor

Betatrol is liquid-level sensor (above) that uses radioactive material in sensing element. Betatrol is mountable in any attitude that permits connection to amplifier by up to 200 ft of cable. Specifications include: temperature range of −65–220° F, operating pressure from vacuum to 800 psig max, accuracy is ±0.05 in. horizontally mounted or, vertically mounted, ±0.10 in.—Robertshaw-Fulton Controls Co., 401 N. Manchester Rd., Anaheim Calif.

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LITERATURE AVAILABLE

Lead-glass production facilities are pictured in 2-p. brochure.—Hayward Scientific Glass Corp., 217 Magnolia Ave., Whittier, Calif.

Electronic-manufacturers directory lists 264 firms, their officers and products in 70-p. booklet.—West Coast Electronic Manufacturers Association, 1435 S. La Cienega Blvd., Los Angeles 35, Calif.

Nuclear instruments are described in 44-p. catalog.—Ekco Electronics Ltd., Southend-On-Sea, Essex, England (U. S. distributor, American Tradair Corp., 34-01 30th St., Long Island City 6, N. Y.)

Density and moisture gage, a portable field instrument, is described in 8-p. catalog.—Nuclear-Chicago Corp., 229 W. Erie St., Chicago 10, Ill.

Engineering and industrial drawings released to public domain by AEC are available.—Cooper-Trent Blueprint & Microfilm Corp., 2701 Wilson Blvd., Arlington 1, Va.

Temperature-control and moisture-measurement instruments are described in three bulletins (2002, 2051, 3885).—Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill.

Metallurgical r & d services are outlined in 4-p. brochure.—Metals Research and Development, Inc., Exeter, Pa.

AccuRay pipewall thickness gage and continuous-flow density systems are described in catalogs NI-157 and NI-158 respectively.—Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.

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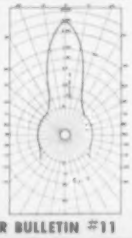

Directional sensitivity of the scintillation counter with LC-2 Lead Collimator Attachment. Note that scale is logarithmetic. This data measured with Iodine 131.

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X-Ray spectrograph application is written up in 2-p. reprint.—Phillips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Gamma irradiation cell is depicted in 4-p. brochure G1C2.—Atomic Energy of Canada, Ltd., P. O. Box 93, Ottawa, Canada.

Absorption cells and other sample-handling accessories for spectrophotometers are described in 12-p. bulletin 729.—Beckman Instruments, Inc., 2500 Fullerton Rd., Fullerton, Calif.

Reactor-operation planning check list is given in 4-p. bulletin.—Nuclear Science & Engineering Corp., P. O. Box 10901, Pittsburgh 36, Pa.

Pulse-Height analyzer, multichannel, is described in 4-p. bulletin 400.—Eldorado Electronics, 2821 Tenth St., Berkeley, Calif.

Signalling controller for electrolytic conductivity is described in 2-p. Data Sheet ND47-95(1).—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.

"Probing the Unknown" is title of 28-p. brochure displaying research facilities and activities in fields of chemistry, computing, electronics and ultrasonics, metallurgy, nuclear power, power plants, etc.—Curtiss-Wright Corp., Quehanna, Pa.

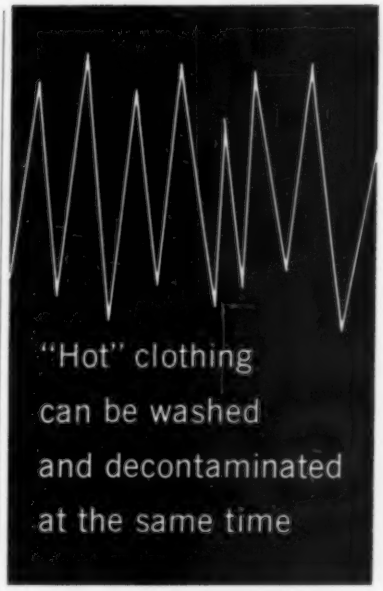
Heat-transfer equipment fabrication facilities are described in 8-p. brochure.—Ross Heat Exchanger Div., American Radiator & Standard Sanitary Corp., Buffalo 5, N. Y.

Lubrication Newsletter gives applications for MoS_2-base lubricants.—The Alpha Molykote Corp., 65 Harvard Ave., Stamford, Conn.

Metallurgy journal giving information on tungsten, molybdenum, tantalum and niobium is issued periodically.—Fansteel Metallurgical Corp., North Chicago, Ill.

X-ray analysis theory is subject of 12-p. booklet.—Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

Multichannel oscilloscope is discussed in 9-p. booklet.—A. E. Cawkell, Electronic Engineers, 6-8 Victory Arcade,



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Department starts on page 122

The Broadway, Southall, Middlesex, England.

"Tubing for Atomic Power" is title of 6-p. Memorandum 20.—Superior Tube Co., 1552 Germantown Ave., Norristown, Pa.

Radiation instrument price list is available.—Radiation Instrument Development Laboratory, Inc., 5737 S. Halsted St., Chicago 21, Ill.

Packless valves are described in 4-p. Bulletin 10-57.—Hoke, Inc., 136 S. Dean St., Englewood, N. J.

X-ray diffraction equipment is discussed in 16-p. catalog.—Compagnie General de Radiologie, 50 Boulevard Gallieni, Issy-Les-Moulineaux (Seine), France.

Reactor-control instrumentation, transistorized, is subject of 21-p. manual.—Fairchild Camera & Instrument Corp., Robbins Lane, Syosset, N. Y.

"Zirconium and Hafnium" is title of 16-p. brochure.—Mallory-Sharon Metals Corp., Warren Ave., Niles, Ohio.

Fuel-element and other core-component fabrication facilities are depicted in 8-p. brochure N-1.—M & C Nuclear, Inc., P. O. Box 898, Attleboro, Mass.

"Valves for Nuclear Reactors" is title of 4-p. bulletin.—Automatic Switch Co., Florham Park 1, N. J.

Tubing applications for nuclear power plants are depicted in 6-p. foldout.—Wolverine Tube Div., Calumet & Hecla, Inc., 17200 Southfield Rd., Allen Park, Mich.

"Newscast" is title of periodical publication devoted to reporting on corrosion-resistant casting, valves, fittings and pumps.—Cooper Alloy Corp., Hillside, N. J.

Closed-circuit television systems are depicted in 8-p. brochure.—General Precision Laboratory, Inc., 63 Bedford Rd., Pleasantville, N. Y.

Gas chromatography, two-column, is discussed in 4-p. Data Sheet GC-82-MI.—Beckman Instruments, Inc., 2500 Fullerton Rd., Fullerton, Calif.

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INDUSTRY NOTES

• **Bell Aircraft** has entered the naval reactor program; its Niagara Frontier div. is making the core barrel and structural core parts for a submarine reactor.

• **The Homestake-Sapin** uranium mill owned jointly by Homestake Mining and Sabre-Pinon went into production during August at half of its rated output of 1,500 tons per day U concentrate. The mill is at Grants, N. M.

• **Davison Chemical claims** the first purchase of U concentrate for conversion to reactor feed material made directly from private sources—in this case, Uranium Reduction Co. Enriched U is available only from AEC.

• **High Voltage Engineering** has cut the price of its 2-million-volt Van de Graaf X-ray generator for cancer therapy by 25%—from $68,500 to $52,000.

• **M. J. Seavy & Co.,** New York, has been named Radiation Counter Laboratories' sales representative in New York, New Jersey and eastern Pennsylvania.

EXPANSIONS. Overseas, **Stone & Webster,** forming a Dutch subsidiary —Stone & Webster Engineering N.V., The Hague—and giving its name to subsidiaries in Britain, France and Australia. . . . **Ebasco Services,** opening an office in Milan under Arnold R. Beardsley, management-marketing consultant. . . . **Radiation Counter Laboratories,** building a new wing to boost plant working space 40% (20,000 sq ft total); plant had been doubled in January. . . . **Metals Research and Development,** Exeter, Pa., expanding fabrication facilities by one third, including new metal powder rolling capability.

NEW FIRMS. In New York City, **Schupack and Zollman,** consulting engineers specializing in reinforced and prestressed concrete tanks, including reactor safeguard shells. . . **Charles Walsh Associates,** Deerfield, Ill., specializing in the sale of nuclear and electronic equipment in a 10-state midwest area. . . **General Mills** and **Savage & Parsons,** Britain, are negotiating formation of a British firm to design and market remote handling equipment worldwide. . . **Lerma Engineering Corp.,** Northampton, Mass., engineering optical instrumentation for nuclear and other use. . . **Ceramics for Industry Corp.,** Mineola, N. Y., manufacturing precision ceramic parts. . . **Metallurgie et Mecanique Nucleaires,** Brussels, design and manufacture of fuel elements of any type; formed by La Fabrique Nationale d'Armes de Guerre and Societe Generale Metallurgique de Hoboken. . . **Nuclear Chemical Plants, Ltd.,** U. K., formed by Power-Gas Corp., John Thompson & Co., and Humphreys and Glasgow, Ltd., for design and engineering of process and treatment plants.

FINANCIAL. First half '58 earnings of **Lithium Corp. of America** were 49 cents a share, compared with 35 cents first half 1957; the firm has been accepted for listing on the American Stock Exchange. . . . **Westinghouse** reported unfilled orders for atomic equipment "considerably above" 1957 in disclosing second quarter 1958 results. . . Sharp gains in sales and earnings for first half 1958 were reported by **High Voltage Engineering**—sales of $2,934,212 and earnings of $206,091 or 54 cents a share; backlog was $5,317,321 on June 30. . . . **Radiation Counter Laboratories** increased sales 26% during the year ended June 30, reaching $1,725,000 on new-product business.

NEW BUSINESS. A $400,000 contract to produce control-rod mechanisms for submarine reactors has been awarded to **Vard Inc.,** Pasadena, Calif., by Westinghouse; Vard is installing "hot test" facilities in anticipation of continuing naval reactor business. . . . **Diversified Builders,** Paramount, Calif., won a $3,620,000 AEC contract covering the second building phase of Experimental Breeder Reactor No. 2 . . . Rochester div. of **Consolidated Electrodynamics** has received a $195,000 order from Brookhaven for high-vacuum pumps to evacuate the 30-Bev synchrotron nearing completion.

COMPANY MOVES. From New York City to Mt. Lakes, N. J. (P. O. Box 415), **William B. Johnson & Associates.** . . . **Ralph M. Parsons Co.** has moved its headquarters to 617 W. 17th Street Bldg., Los Angeles. . . . New address of **George A. Philbrick Researches** is 285 Columbus Ave., Boston.

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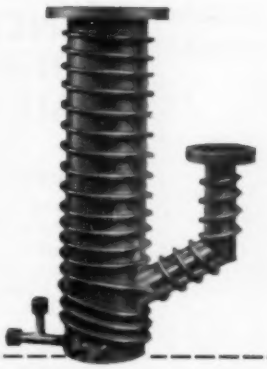

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NUCLEAR CAMPUS

• **University Reactors.** A special reactor for teaching purposes is expected to be operating at **Iowa State College** by the end of the current school year; AEC has granted $150,000 for the unit. . . . **Texas A & M** has selected Convair div. of General Dynamics to design its $826,000 nuclear science center; the center's reactor will be a high-power, pool-type. . . . AEC has presented a 10-kw Argonaut reactor to the **University of California at Los Angeles**; it will be ready for operation in a year.

• **Nearly 70% of the 120 students** enrolled in an accelerated program to upgrade French nuclear technicians washed out of the course during its first year, which ended July 31. The program consists of two years of night courses in physics, mathematics, quantum mechanics and foreign languages at the Saclay research center; a year of full-time study at the Arts et Metiers engineering school; and a year of thesis preparation in the labs of the French AEC—four years instead of seven.

• **AEC has awarded** $3,630,038 in new and renewed physical research contracts to a long list of universities and research organizations. The two largest contracts, totaling $1,232,500, went to **Yale Univ**: one for $625,000 will permit Yale to buy an electron linear accelerator; the other for $607,500 calls for research work with a heavy ion accelerator already installed.

• **AEC reactor development officials** are bemoaning the fact that they have only $2.5-million in their present budget for nuclear equipment grants to universities and colleges. Pending applications total $6-million, of which $4-million would probably be granted if AEC had the funds.

• **Campus Notes.** Max W. Carbon, thermodynamics expert, has taken on direction of the nuclear engineering program at the **University of Wisconsin**. . . . The Ford Foundation has granted $80,000 to the **University of Michigan** for four years of research on international aspects of atomic energy law. . . . AEC has lent **Case Institute** small amounts of plutonyl-nitrate and plutonium-beryllium for the production and study of radioisotopes. . . . **Syracuse Univ.** has ordered a reactor simulator from Minneapolis-Honeywell.

NEWSMAKERS

K. H. Sun, advisory engineer in charge of the radiation and nucleonics laboratory at Westinghouse, is taking a 10-months' leave this fall to teach nuclear physics, chemistry and/or engineering at the Institute of Nuclear Science, Formosa. **Stanley Ruby** will fill his post until his return.

James B. Kelley, radiation consultant to the State of New York, has returned as technical director, Physics Research Laboratories, after an absence of several years. He will continue as a staff member of Byrne Associates concerned with radiation shielding, safety and laboratory design.

Westinghouse has selected **V. V. Schlosser,** 15-year veteran of the firm, to fill a new post: manager of engineering in the atomic equipment dept.

New staff members at Brookhaven National Laboratory are: **Herbert H. Bolotin, Leon F. Landovitz, David A. Young** and **Martin S. Zucker,** physics dept.; **Shigeru Oae** and **Edwin Roig,** chemistry; and **Irving Schwartz** and **Yasokazu Yamamoto,** medical.

Nuclear Development Corp. of America has filled two important positions. **Howard Schwartz,** a mechanical engineer and former deputy chief of the civilian reactor branch of AEC's reactor development div., has been named assistant to NDA President John R. Menke.

Schwartz

Thomas Donald Hawkins, another mechanical engineer, has been named manager, engineering test section. Schwartz, a five-year man with AEC, was one of several key men in the reactor development div. to leave the Commission in the last few months; he joined the AEC from the atomic energy dept. of North American Aviation. Hawkins was a senior development engineer at Walworth Co., Boston, before he joined NDA.

Hawkins

Two important personnel developments at Argonne National Laboratory: **Roger H. Hildebrand** has been named associate director of the facility for high-energy physics; and **James A. DeShong, Jr.,** has taken six-months' leave to direct stability tests during startup of the boiling heavy water reactor at Halden, Norway. Hildebrand was associate professor of physics at the Univ. of Chicago's Enrico Fermi Institute for Nuclear Studies, where he was working on mu-meson–nucleon interactions. DeShong heads the control section of ANL's reactor engineering div.; his assignment to Halden was arranged during a visit of two Norwegian scientists to the Laboratory.

Hildebrand

DeShong

In another development at Argonne, **John J. Livingood** resigned as director of the particle accelerator div.; he was succeeded by **Albert V. Crewe** of the Univ. of Chicago. Livingood will return to full-time work on basic research problems as a member of Argonne's physics div.

Leaving his post as manager of American Machine and Foundry's nuclear lab, Greenwich, Conn., **Chris J. Brous** has joined Atomics International as assistant chief of engineering.

Capt. Edward W. Hribar (USN) has been assigned to the aircraft reactors branch of AEC as deputy for naval applications. Simultaneously he has taken on direction of nuclear propulsion at the Bureau of Aeronautics, leading the effort to develop a nuclear seaplane.

W. J. Buffo has moved to Radiation Instrument Development Laboratory as sales manager from his post as acting sales manager, Radiation Counter Laboratories.

Clayton C. Carroll has been named head of engineering at United States

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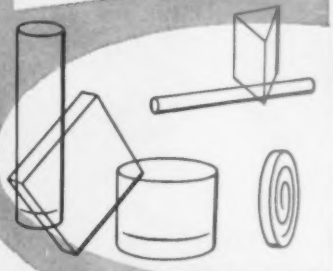

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NEWSMAKERS

Department starts on page 135

Radium Corp; Carroll will also continue as company research coordinator. His appointment as engineering head will enable consolidation of several USR operations, including design, methods, process engineering, planning, estimating and quality control.

A former British metallurgist, **Jack Preston,** has been named chief research metallurgist for special metals at the Watervliet, N. Y., research laboratory of Allegheny Ludlum Steel. He will direct research work on zirconium, uranium, tantalum and other special metals. Preston has been in the U. S. for three years, employed since his arrival by Titanium Metals Corp. of America, jointly owned subsidiary of Allegheny and National Lead.

Preston

Errol W. Doebler, board chairman and chief executive officer of Long Island Lighting, has been named to the board of the American Standards Assn. Doebler has taken an active part in ASA's nuclear energy program for some time.

Victoreen Instrument's **Earl Pollock,** director of technical services, has taken a one-year's leave of absence to assume direction of a special training course in radioisotopes at the Oak Ridge Institute of Nuclear Studies. The course, placing emphasis on industrial applications, has been set up as a part of AEC's radioisotope development program.

Pollock

Varian Associates has promoted **Victor G. Aleshin** from assistant manager to manager of manufacturing in the instrument div.

Trio Machine Works has elected **Stephen F. Malaker,** nuclear consultant, to the board of directors. Malaker is president of his own firm and professor of nuclear engineering at Newark College of Engineering.

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NUCLEAR CALENDAR

Oct. 22–25—Eleventh Annual Gaseous Electronics Conference, New York City (*Barbizon-Plaza*), sponsored by the division of electron physics, American Physical Society, and Bell Telephone Laboratories. Emphasis on thermonuclear experiments. Contact D. J. Rose, Bell Labs, Murray Hill, N. J.

Oct. 27–30—Fall meeting of The Metallurgical Society, American Institute of Mining, Metallurgical and Petroleum Engineers, Cleveland (*Public Auditorium*). Program includes two sessions on fuel element fabrication and presentation of a summary of powder metallurgy highlights at the Geneva conference on peaceful uses of the atom. Contact the Society at 29 W. 39th St., New York 18.

Oct. 28–31—Classified symposium on radiation effects sponsored by the Air Research and Development Command, U. S. Air Force, Atlanta (*Dinkler Plaza*). Contact Lockheed Aircraft Corp., Marietta, Ga.

Nov. 6–7—Sixth annual meeting, Professional Group on Nuclear Science, Institute of Radio Engineers, San Mateo, Calif. (*Villa Hotel*). Four sessions. Contact H. Malcolm Ogle, General Electric, San Jose, Calif.

Nov. 9–12—Annual meeting, Atomic Industrial Forum, Washington, D. C. (*Shoreham*). Contact E. Wiggin, 3 East 54th St., New York 22.

Nov. 18–20—Ninth national conference on standards, sponsored by American Standards Assn., New York City (*Roosevelt*). Session on nuclear codes Nov. 19. Contact K. G. Elsworth, ASA, 70 E. 45th St., New York 17.

Nov. 28–29—American Physical Society, Chicago (*Univ. of Chicago and Windermere Hotel*). Contact K. K. Darrow, Columbia Univ., New York 27.

Dec. 1–5—23rd National Exposition of Power and Mechanical Engineering, New York (*Coliseum*). Sponsored by American Society of Mechanical Engineers. Concurrent technical sessions of Nuclear Engineering div., ASME. Contact International Exposition Co., 480 Lexington Ave., New York 17.

Dec. 8–10—Winter meeting, American Nuclear Society, Detroit. Contact Octave DuTemple, 86 E. Randolph St., Chicago.

Jan. 28–29—First International Symposium on Nuclear Fuel Elements, Columbia Univ., New York. Sponsored jointly by Columbia and Sylvania-Corning Nuclear Corp. Contact H. H. Hausner, 730 Fifth Ave., New York 19.

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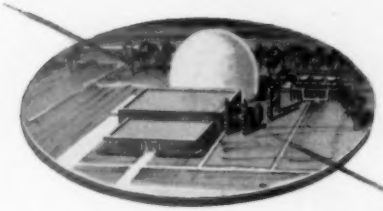

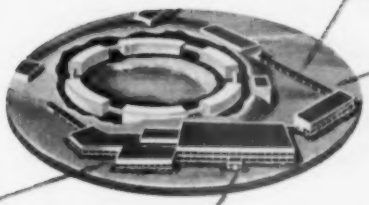

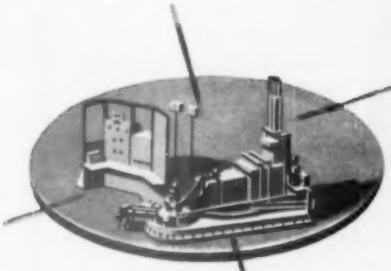

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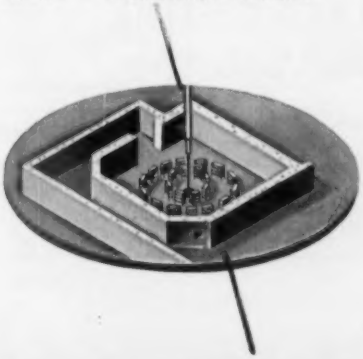

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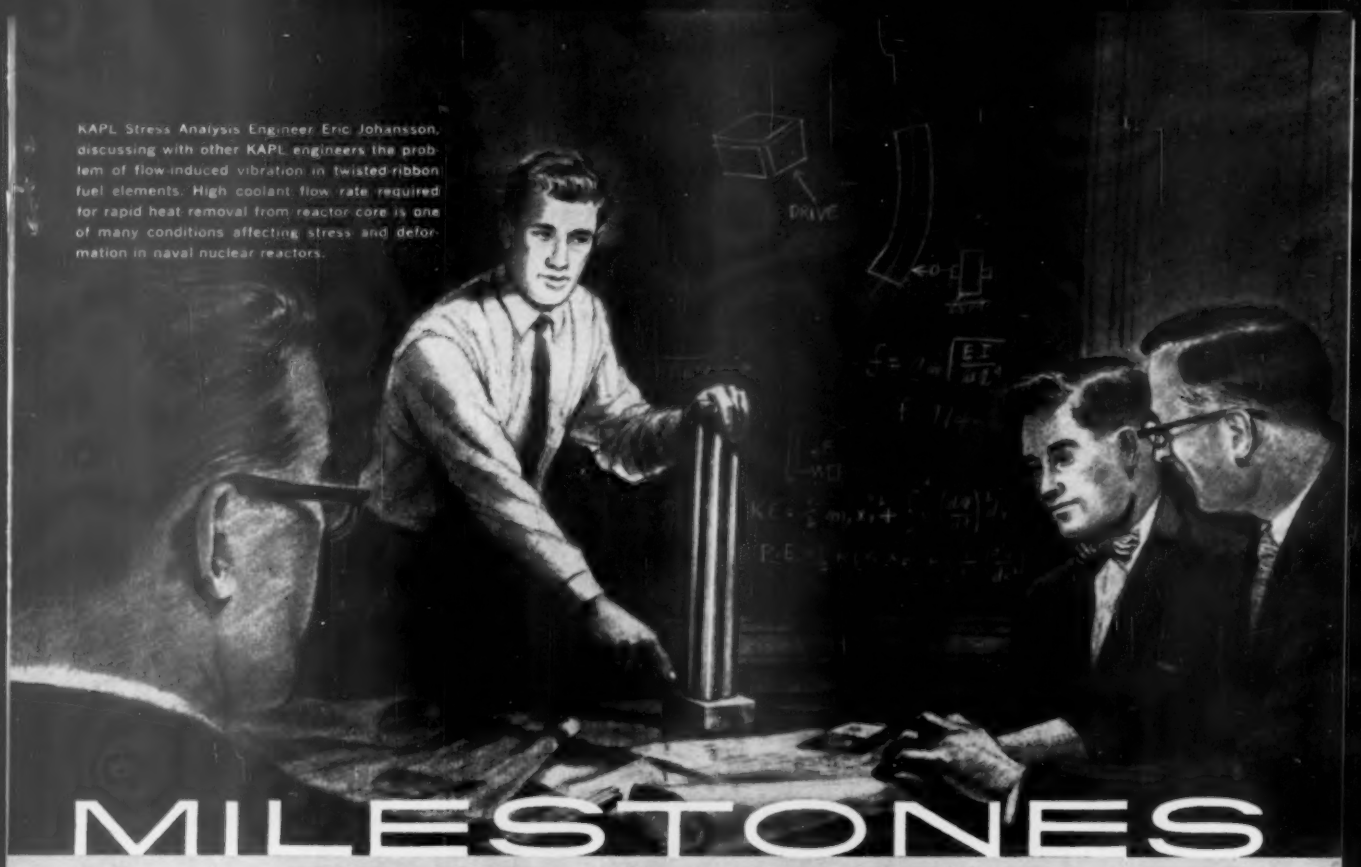

KAPL Stress Analysis Engineer Eric Johansson, discussing with other KAPL engineers the problem of flow-induced vibration in twisted-ribbon fuel elements. High coolant flow rate required for rapid heat removal from reactor core is one of many conditions affecting stress and deformation in naval nuclear reactors.

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Eric B. Johansson is one of approximately twenty Stress Analysis Engineers working on naval reactors at KAPL. Eric joined G.E. in 1951 following graduation from the California Institute of Technology and graduate study at UCLA. He has completed advanced study in engineering analysis as a graduate of G.E.'s Advanced Engineering Program and has taken additional graduate work at Rensselaer Institute of Technology under G.E.'s Tuition Refund Program.

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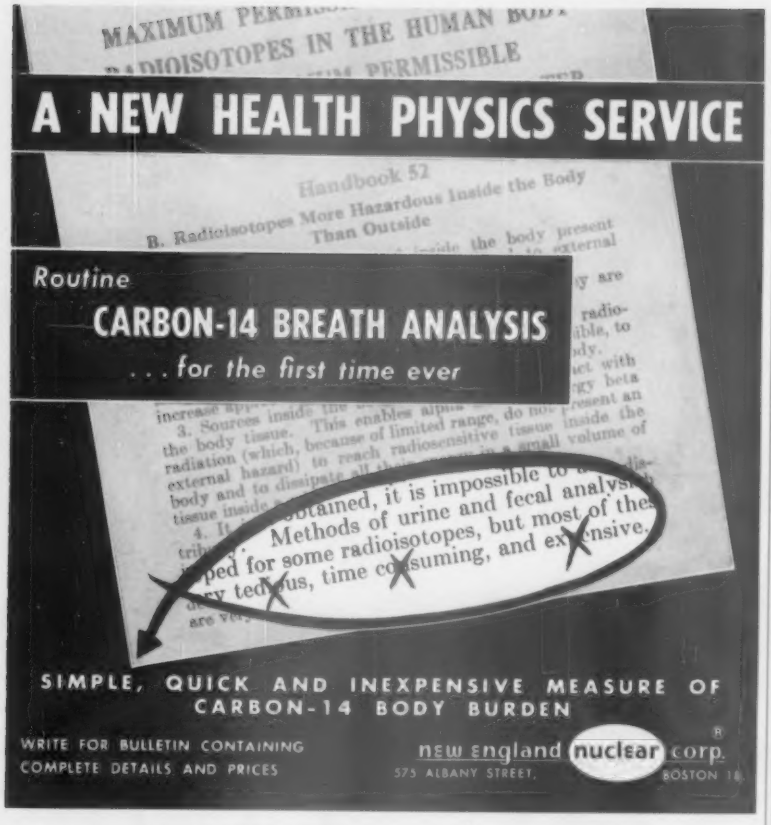
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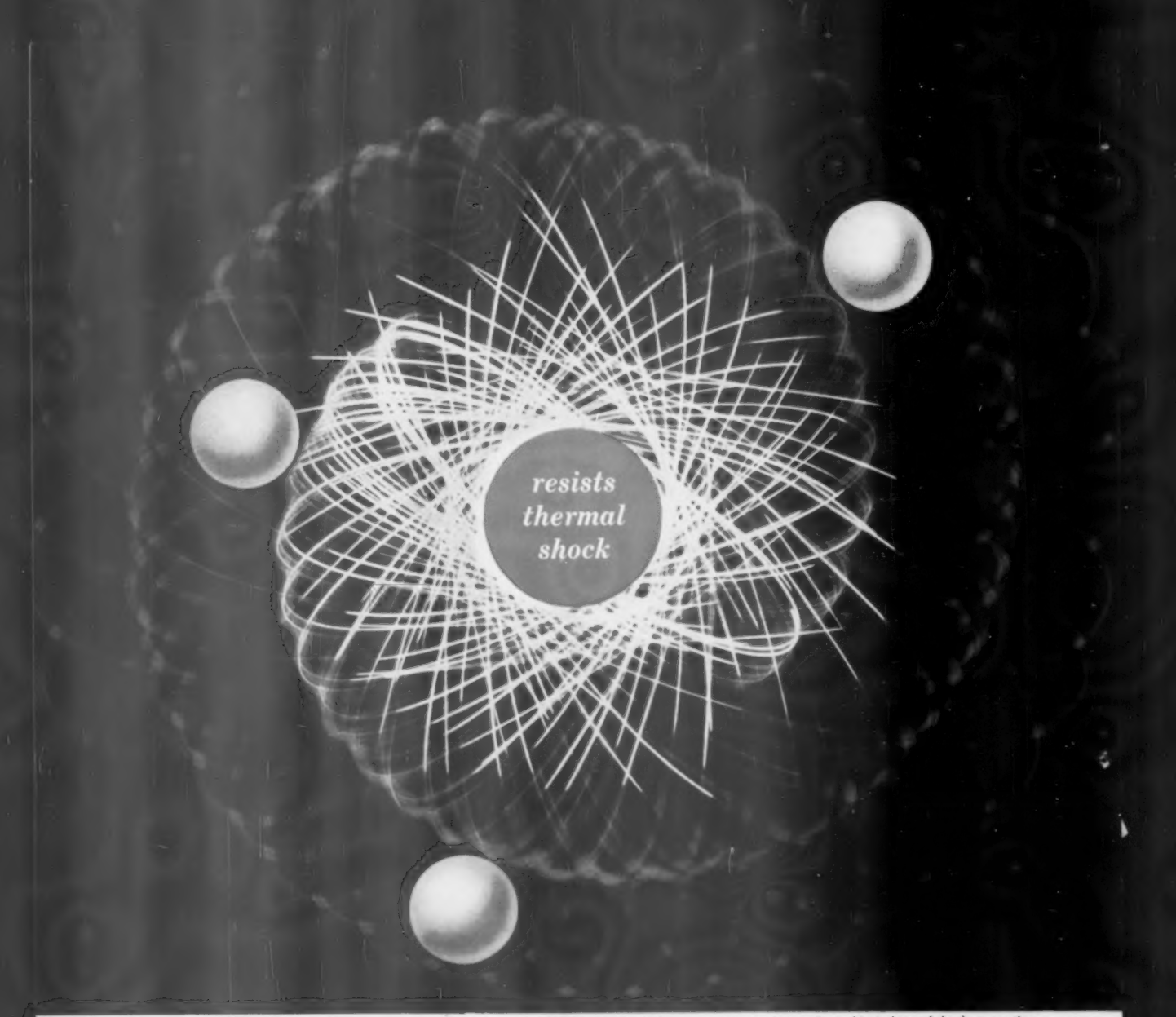

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